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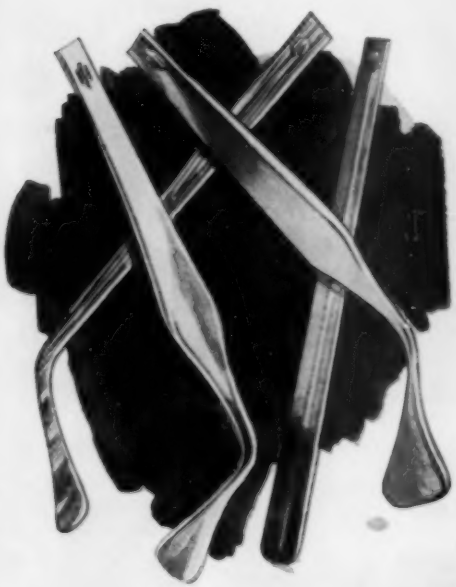

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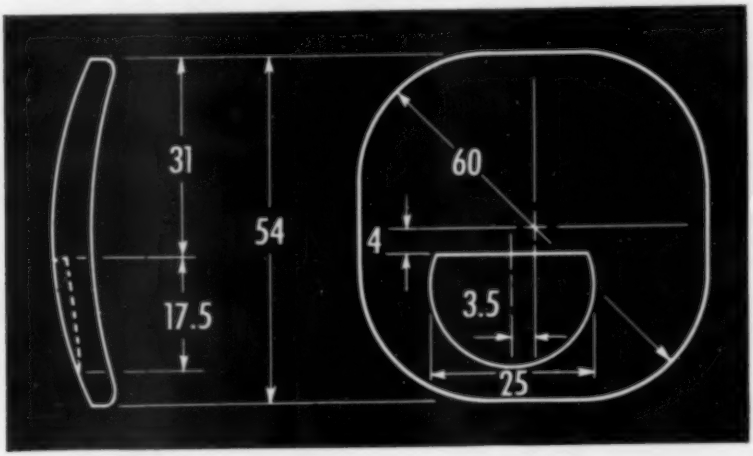

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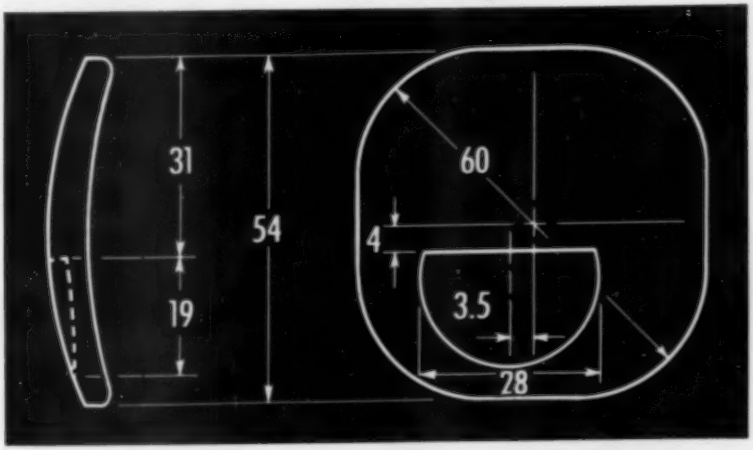

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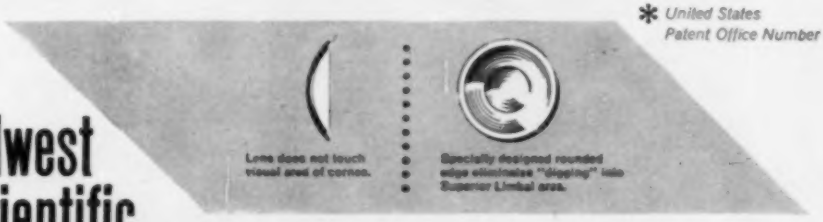
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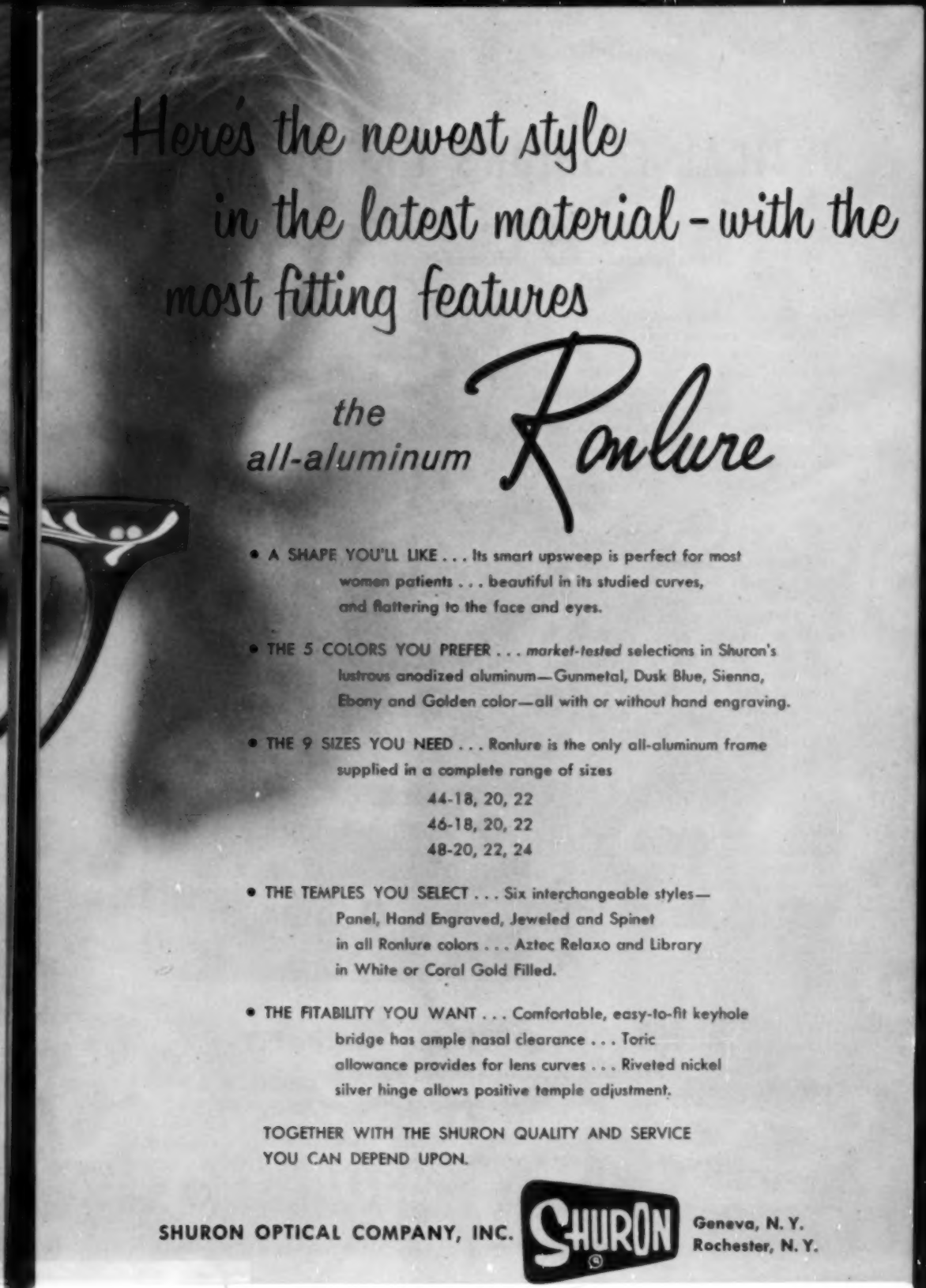
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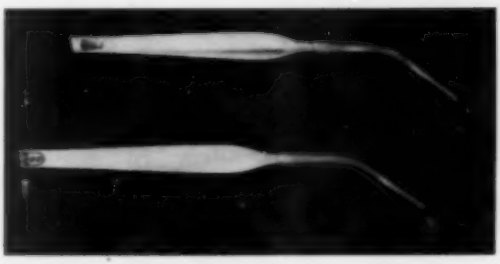

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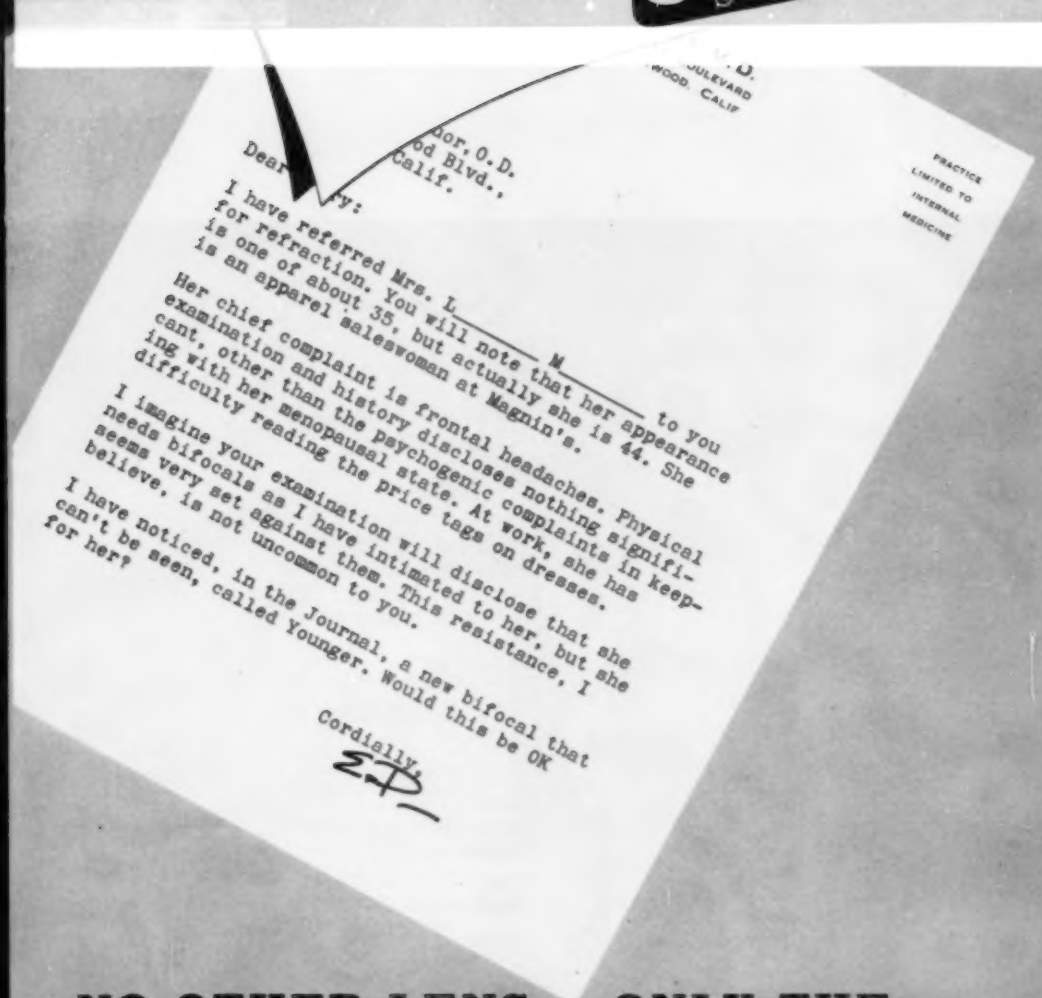
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Vol. 35 June, 1958 No. 6

CHANGES IN REFRACTION OVER A PERIOD OF TWENTY YEARS IN A NONVISUALLY SELECTED SAMPLE*

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School of Optometry, University of California
Berkeley, California

If we are to understand the changes which occur in refraction with age, it will be necessary to study the changes in a nonvisually selected sample of the population. Previous studies have been either largely concerned with samples which have been selected from clinical sources and thus may be assumed as having visual defects to a greater degree than the general population or with nonvisually selected samples which have different individuals at each age level. The first type of study is exemplified by a recent one of Baldwin,[1] the second by one of Hirsch.[2] The study reported here is a longitudinal study on a nonvisually selected sample. The span of the study is twenty years. The individuals were 13 years old when first investigated and 33 years old the last time they were seen.

THE NATURE OF THE SAMPLE

A continuing long-term study of growth and development of children has been underway at the Institute of Child Welfare at the University of California, under the direction of Professor Harold E. Jones, for many years. One of the groups studied was made up of about 150 boys and girls entering the seventh grade. These youngsters were chosen from two junior high schools in the city of Berkeley, California. The only selection factor was parental and child consent to take part in the study.

In 1934 and 1935 optometric data were collected under the direction of Professor F. L. Mason§ of the School of Optometry on this group of children. The mean age of the sample was 13 years. These same children were also studied for several more years by members of the Institute staff.

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*Read before the annual meeting of the American Academy of Optometry, Chicago, Illinois, December 7, 1957. For publication in the June, 1958, issue of the AMERICAN JOURNAL OF OPTOMETRY AND ARCHIVES OF AMERICAN ACADEMY OF OPTOMETRY.

†Optometrist, Ph.D., Member of faculty, Fellow, American Academy of Optometry.

§Deceased.

In 1953, Professor Hardin Jones, who has an interest in the aging process, secured funds from the Guggenheim Foundation to pay the expenses incurred in bringing back to Berkeley as many of this group as possible in order that the physical and mental changes which had occurred might be noted. Since optometric data were available on these subjects, the School of Optometry was included in this study. As a consequence of the interest of Professors Hardin Jones and Harold Jones, members of the staff‡ of the School of Optometry had an opportunity to examine 51 women and 44 men from the original group. The mean age of these subjects when examined in 1954-56 was 33 years.

In the interest of clearness and simplicity, the early examinations will be referred to as the '34 examinations and the latter ones as the '54.

THE NATURE OF THE 1934 EXAMINATIONS

In 1934, approximately one-half of the examinations were performed by Professor Mason and one-half by fourth-year students in the School of Optometry working in teams of two. The present author was one of the students who worked on this study in the Spring of 1934. Most of the boys and girls were seen three times twenty years ago: once in the Spring of 1934, in the Fall of 1934 and again in the Spring of 1935. The students who worked in the Spring had had one semester of clinical experience, while those who worked in the Fall did not. Consequently, the Spring data are probably more valid than the Fall.

Unfortunately, the original raw data obtained in 1934 cannot be located at this time. The data now available are in the form of tables prepared under Professor Mason's direction. One cannot now tell Professor Mason's data from that obtained by the students working under him. In certain instances the tabular data are not as meaningful as the raw data would have been (see Ophthalmometer Cylinder for an example).

The measurements made in 1934 which are available at present are: visual acuity without corection and with correction, interpupillary distance, corneal astigmatism determined by the ophthalmometer, static skiametry, subjective refraction, heterophoria at 6 meters, base-out prism vergence for 6 M., base-in prism vergence for 6 M., amplitude of accommodation, dynamic skiametry, and the accommodative convergence which had been calculated from the distance and near heterophoria measurements. From the data, the calculations can be reversed and the heterophoria for 40 cms. fixation distance can be determined.

‡Prof. M. W. Morgan, Dr. Duco Hamasaki, Dr. Merton Flom, Dr. Fred Marcus, Dr. Robert Harrigan, and Dr. Gordon Heath.

In addition to the above, observations were made as to the presence, or absence, of pathological changes and to the ability to read correctly the plates in an Ishihara pseudoisochromatic color book. These plates were exposed in ordinary daylight.

Comments concerning certain peculiarities of the data will be made below where each of the various measurements are discussed.

THE NATURE OF THE 1954 EXAMINATIONS

In 1954, these same subjects were re-examined. This time only persons of the clinical staff of the School of Optometry served as examiners. It may therefore be assumed that the 1954 data are more valid on the whole than those obtained in 1934.

The same set of data was obtained as in 1934 with certain additions. The measurements which were repeated were made in nearly the same manner as possible as those made twenty years earlier, except for the determination of color vision. The added measurements were: positive and negative relative accommodation, and positive and negative relative convergence. The flicker fusion frequency for a standard luminance was also determined. Certain individuals found to be color deficient were given additional tests in order to identify the particular anomaly of color vision. The accommodative convergence using the haploscope was also determined.

TREATMENT OF THE DATA

The mean and standard deviation of the test results for each test in 1934 and 1954 were calculated for the males and females separately. The differences in the means and the variances were then determined with respect to a confidence limit of 5% by the t test and F test, respectively. The coefficient of correlation between the '34 and '54 data was also calculated along with the 95% confidence limits for the coefficient. In certain instances, noted below, other statistical methods were used in addition to these just mentioned.

Below is a report of the results obtained for each test which was made in 1934 and again in 1954. In every instance the data given under the heading 1934, was that obtained in the Spring of 1934 without regard to that obtained in the Fall of 1934 and the Spring of 1935. The results are summarized in Tables 1, 2 and 3.

CORRECTED VISUAL ACUITY

The corrected visual acuity obtained in 1954 was the same as, or slightly better than, that obtained in 1934 in every instance.

INTERPUPILLARY DISTANCE

The interpupillary distance was determined in 1934 by means of a Zeiss interpupillary gauge which allowed for the determination of the

interpupillary distance for distance fixation. In 1954 the interpupillary distance was determined by the usual means normally employed by optometrists; namely, the distance between the inner edge of one pupil to the outer edge of the other was determined while the subject maintained fixation above, or below, the examiner's right eye and then the examiner's left eye in turn. An ordinary P.D. rule was employed. The means and standard deviations for the females and males are shown in Tables 1 and 2.

TABLE OF TEST RESULTS ON FEMALES

TABLE 1

Test	1934 Mean Std. Dev.	1954 Mean Std. Dev.	Change Mean	Change Variance	r	95% Limits r
P.D.	59.7 ±2.6	62.8 ±2.7	S	–	+0.72	±0.15
Ophth. Cyl.	+0.69±0.53	+0.91±0.74	S	S	+0.54	±0.11
Rx Cyl.	—0.14±0.61	—0.26±0.73	S	S	+0.51	±0.10
Rx 180°	+0.15±1.03	—0.01±1.46	–	–	+0.80	±0.07
Rx 90°	+0.03±1.08	—0.25±1.57	S	S	+0.70	±0.12
Phoria	+0.8 ±3.3	+0.4 ±2.6	–	S	+0.69	±0.12
Add.	13.6 ±5.8	15.2 ±3.3	–	S	—0.24	±0.24
Abd.	8.8 ±3.5	6.5 ±2.9	S	–	+0.07	±0.27
Amp.	11.96±2.85	6.84±1.94	S	S	+0.26	±0.17
Dynamic	+1.60±0.64	+1.64±0.39	–	S	+0.29	±0.24
F.S.C.#	—1.6 ±4.3	—3.9 ±4.9	S	–	+0.64	±0.14
Ac.-Conv.	12.4 ±4.2	10.9 ±3.6	S	–	+0.36	±0.21

S—significant difference. A difference as great as that indicated would be expected, by chance, no more than 5% of the time.

#F.S.C.—Fusional Supplementary Convergence, the phoria with fixation 40 cms. in advance of the spectacle plane.

The coefficient of correlation for the measurements of '34 and '54 was for the females +0.72 and for the males +0.82. It is apparent that at the age of 13 there is no difference in interpupillary distances between boys and girls, but there is a difference between men and women. The fairly high coefficient of correlation and the small variance change indicates that the increase in P.D. was fairly uniform so that most of those with a large P.D. in 1954 had a large P.D. in 1934.

OPHTHALMOMETER CYLINDER

Unfortunately, the exact curvatures of the corneas measured in '34 are not available; only the differences between the two principal meridians were recorded on the tables which we now have.

In order to analyze the data statistically, it was assumed that "with the rule" corneal astigmatism was plus, and "against the rule" was minus. Oblique corneal astigmatism was omitted from the calculations. "With the rule" was defined as the condition in which the meridian of least curvature was between 150° and 180° or between 0° and 30°. "Against the rule" was defined as the condition in which

TABLE OF TEST RESULTS ON MALES

TABLE II

Test	1934 Mean Std. Dev.	1954 Mean Std. Dev.	Change Mean	Change Variance	r	95% Limits r
P.D.	59.8 ±2.9	65.7 ±2.9	S	–	+0.82	±0.06
Ophth. Cyl.	+0.41±0.61	+0.58±0.84	S	S	+0.30	±0.17
Rx Cyl.	—0.08 ±0.36	—0.03±0.45	–	S	+0.47	±0.15
Rx 180°	+0.37±0.54	+0.31±1.02	–	S	+0.56	±0.12
Rx 90°	+0.42±0.56	+0.39±0.93	–	S	+0.44	±0.19
Phoria	+0.4 ±3.2	+1.1 ±2.8	–	–	+0.68	±0.12
Add.	12.5 ±5.6	16.6 ±5.0	S	–	+0.10	±0.22
Abd.	5.1 ±3.3	5.6 ±1.6	–	S	—0.21	±0.24
Amp.	12.34±2.15	6.92±1.28	S	S	+0.19	±0.19
Dynamic	+1.20±0.46	+1.81±0.41	S	–	—0.02	±0.43
F.S.C.#	—2.7 ±5.1	—4.2 ±3.4	S	S	+0.63	±0.13
Ac.-Conv.	11.8 ±3.9	11.4 ±2.9	–	S	+0.39	±0.20

S—significant difference between '34 and '54 data. A difference as great as that indicated would be expected, by chance, no more than 5% of the time.

#F.S.C.—Fusional Supplementary Convergence, the phoria with fixation 40 cms. in advance of the spectacle plane.

the meridian of least corneal astigmatism was between 60° and 120°.

Oblique corneal astimatism was reported in three eyes (2 individuals) in 1934 and four eyes (2 individuals) in 1954. One subject had oblique astigmatism, both in 1934 and 1954. Consequently, the change in corneal astigmatism was not calculated for these three subjects because of oblique corneal astigmatism. One other subject was not included because the corneal curves were beyond the range of the ophthalmometer in 1954. The results of the calculations are given in Tables 1 and 2.

Within the limits noted in Tables 1 and 2, we may conclude that the corneas of the females appear to have changed, becoming more curved in the vertical meridian with time. On the other hand, the relative curvatures of the male cornea do not change significantly from age 13 to age 33.

The coefficient of correlation for the females was larger than that for the males. This, together with the change in means and the larger variance for the males, probably indicates that the changes in the corneal curves were of a more random nature in the males than in the females.

One might speculate that lid pressure induces this observed change and that it is greater in females than males because of greater softness of the tissues.

REFRACTIVE ERROR

In view of the apparent change in the vertical meridian of the cornea of females and the difficulty of interpreting refractive data presented as equivalent spheres, it was decided to analyze the subjective

refractive findings in terms of the power in the 180° and 90° meridian and the power of the cylinder. When a cylinder was found whose axis was not 90° or 180°, the power in these two meridians was calculated by using the formula P_{90} or $_{180} = P_C \sin^2 \theta$ (a simplified version of Euler's formula) where P_C is the power of the cylinder and θ the angle between the axis of the cylinder and 90° and 180° in turn.

The analysis dealing with the correction cylinder was made on the basis of whether the astigmatism corrected by the cylinder was "with the rule," "against the rule" or oblique. "With the rule" was defined for purposes of the analysis as any minus cylinder whose axis was between 150° and 180° or between 0° and 30°. "Against the rule" was defined as any minus cylinder whose axis was between 60° and 120°. Oblique cylinders were then those whose axis was between 30° and 60° or between 120° and 150°. "With the rule" cylinders were represented by minus numbers equivalent to the power of the minus cylinder, "against the rule" were represented by plus numbers equivalent to the power, and "oblique" cylinders were omitted entirely. The sign given the correction cylinder was opposite that given the ophthalmometer cylinder. Thus, a minus correction cylinder corrected for a plus ophthalmometer cylinder.

The mean and the standard deviation were calculated for the cylinder, the power in the 90° meridian and the power in the 180°. This method of analysis tends to give added weight to the few extreme measurements. In order to avoid this effect of the high errors, one could use the median and the interquartile range. Unfortunately, these two statistics cannot easily be used in the determination of other relationships.

The mean values and the standard deviations of the various factors in the refractive error are shown in Tables 1 and 2. The data on the correction cylinder are, of course, similar to the differences between the 180° and 90° meridians. In the case of the correction cylinder, as in the case of the ophthalmometer cylinder, the real change appears to take place in female eyes. This change is a slight increase in the "with the rule" astigmatism. The coefficient of correlation between the change in the ophthalmometer cylinder and the correction cylinder in females was found to be 0.51. The mean change in the opthalmometer cylinder was 0.23 D. ± 0.64 D. while that of the correction cylinder was 0.16 D. ± 0.63 D. The differences between these two are not significant.

The change in the twenty-year period, as far as the refraction is concerned, is a slight change toward myopia in the vertical meridian

of female eyes. This agrees with the analysis of the ophthalmometer data and the correction cylinder data. The other change which did occur in the twenty-year period is the increase in the variance of the refractive error, indicating a continuation of the process noted in school children by Hirsch.[2]

It should be noted that the coefficients of correlation for these changes (ophthalmometer, cylinder, refraction 90°, and refraction 180°) are all higher for females than for males. Thus, it would appear that the changes which occur in the refractive errors of females from ages 13 to 33 are perhaps more orderly while those in males are more random. This tendency for a more uniform change in female eyes could indicate that the actual changes in the male eyes might be greater even though the mean of the changes are actually less. For example, if we had three individuals whose changes in refraction had been 0 to +0.75, +1.00 to +1.75, +0.75 to +1.50, then the mean change of this group would be +0.75. On the other hand, if we had another group in which the changes had been 0 to —2.00, 0 to +1.00, and +1.00 to +2.00, then the mean change for the group would be zero, even though every individual had changed more than any individual in the first group.

The type of change noted above would lead to an increase in the variance. For the first group the variance (standard deviation squared) is zero, but for the second group it is slightly more than 6.0.

The variance for the change in the refraction for the females for the 90° meridian is 1.25 D. and for the 180° it is 0.77 D. In the case of the males, the variances for the 90° meridian is 0.72 D. and for the 180° meridan it is the same. The difference in the variance in the 90° meridian is significant and since the females have the greater variance, the hypothesis advanced above can be rejected. The refractive changes in the vertical meridian, at least in male eyes, are not only more random but they are also less in amount, on the average, than in female eyes.

HETEROPHORIA - 6 METER

The heterophoria was determined by the von Graefe method of prism displacement.

The mean and standard deviations of the phoria for males and females are given in Tables 1 and 2. The data include the measurements of all individuals in the study group except for two males and one female. These three individuals had an esotropia in 1934 and they still had esotropia in 1954. The percentage of those with strabismus in this nonvisually selected sample was thus 3.2%.

BASE-OUT PRISM VERGENCE - 6-METER FIXATION (ADDUCTION)

Professor Mason advocated the measurement of the motor fusion range by a technique not ordinarily employed and so a short description of the method used is in order.

The subject fixated a 20/200 letter, usually an E. An occluder was then held before the eyes obstructing the subject's vision in both eyes. While the occluder was in place, a prism of low magnitude was inserted before each eye. The occluder was then removed and the subject was requested to report his impressions. If the 20/200 letter was seen as being single (haplopic), the occluder was again placed before the eyes and the prism power increased, usually in 2 to 4 prism diopter steps for the distance base-out vergence and in 1 to 2 prism diopter steps for the distance base-in vergence. This process was continued until the patient reported continued insuperable diplopia when the occluder was removed. This prism value was then the amount which could be overcome. As a rule, this would also be the amount recorded as representing the vergence. In his last years, Professor Mason would record the highest value obtained which allowed for the maintenance of fusion.

Theoretically, the eyes should turn to the fusion-free (phoria) position while the occluder is in place. A good approximation of the fusion-free position is probably attained if the occluder is held before the eyes a fairly long time. As a rule, subjects will report that on first seeing the target on the removal of the occluder that it appears double and immediately, at first, the two images "jump together." As the limits of the fusion range are approached, the time between "double" to "single" vision usually increases. This technique frequently will allow the astute clinician to make qualitative judgments while gathering quantitative data.

This particular technique was called the "reflex method" by Professor Mason and is akin to the "jump-duction" method. The mean values and the standard deviations obtained are reported in Tables 1 and 2.

BASE-IN VERGENCE - 6 METER

The mean and standard deviations are recorded in Tables 1 and 2.

COMMENT ON THE VERGENCES

It is extremely difficult to attach much significance to the changes noted, except to point out that there appears to have been some tendency for the variance of the measurements to decrease during the 20 years between 1934 and 1954.

One thing that can be appreciated from the raw data which is not

readily apparent from the examination of the statistics mentioned above, is that these measurements demonstrate what appears to be the phenomenon of regression. For example, the base-out prism vergence of males in 1934 was 12.5Δ ± 5.6Δ. There were eight individuals whose prism vergence was as great as, or greater than, 12.5 + 5.6Δ and seven whose vergence was as little as, or less than, 1.25 —5.6Δ. None of the individuals who had the large vergence in '34 had one as great in 1954. None of them who had a small vergence in '34 had one as small in 54. The mean value of the large vergence group was 20.6Δ in 1934 and 14.0Δ in 1954. The mean value of the small vergence group was 4.7Δ in 1934 and 15.0Δ in 1954. In this case there was a tendency to find the 1954 value to be higher than the 1934 value if this latter was low. The reverse was true also. Thus, there was a regression toward the mean.

The small vergence group had an increase in this function such that the mean was significantly higher than the mean for the whole group. This is somewhat surprising since usually with regression phenomenon the regression is toward the mean so that the second value is not significantly different than the mean. The assumption that this increase might be due to a kind of continuous orthoptic training through use is untenable since this would not be expected to increase the function to this extent. This process of continuous use would need to be some process which caused a change toward the mean of both the high and the low vergence. It is more likely that the phenomenon being discussed is a manifestation of "error of measurement."

AMPLITUDE OF ACCOMMODATION

Both in 1934 and 1954 the amplitude of accommodation was measured by the Donder's method, commonly referred to as the "push-up" method. Considerable care was taken to record the finding accurately and to avoid the problems induced by the portions of the phoropter which tend to interfere with the approach of the target nearer to the spectacle plane than ten centimeters by use of a special card holder. The amplitude was measured with respect to a plane 14 mm. in advance of the eyes. The means and standard deviations of the amplitude of accommodation are recorded in Tables 1 and 2.

It is interesting to note the very low coefficient of correlation. From the Wallace-Snedecor tables a coefficient of correlation for the number of degrees of freedom would have to be 0.27, or higher, before it could be assumed to be significantly greater than zero. These coefficients are less than this although that for the female subjects approaches this value.

Some idea of the type of change which occurred during the twenty-year interval can be gained by comparing two groups of female subjects: those whose amplitude in 1954 was as great as, or greater than, 8.78 D. (mean +1 S.D.) with those whose amplitude in 1954 was as little as, or less than, 4.90 D. (mean —1 S.D.). There were nine individuals in the first group and seven in the second.

The mean amplitude in 1934 for the first group was 12.75 D. and for the second it was 10.67 D. The mean loss for the first was 3.00 D. and for the second 6.39 D. The difference in the 1934 amplitude is significant at the 2% level.

One can say that those individuals who had a low amplitude of accommodation at age 33 probably lost a greater amount due to the aging process than did those subjects with a high amplitude. One cannot state with any confidence what the amplitude of these individuals had been twenty years previously.

It is well known that there is an excellent coefficient of correlation between age and amplitude. The statements above seem to be in conflict with this idea. There are, however, two factors which must be kept in mind. First, amplitude-age tables are based on cross section rather than longitudinal studies and secondly, there is a large decrease in the variance of the amplitude between individuals as age increases. In other words, the acceptable limits for a normal amplitude decreases with increasing age. If this is true, it must mean that some individuals lose amplitude faster than others, and, in general, one might expect that those who lose amplitude most rapidly are those who initially have a high rather than low amplitude of accommodation. If the loss were uniform the accepted range would also have to be uniform. The data here, however, tend to indicate that the reverse is true—those with a low amplitude in '34 lost amplitude more rapidly than did those with a high amplitude. This could mean that whatever processes are involved in the rate of amplitude loss, they had already started to have an effect when these subjects were 13 years of age.

While it is true that there was found to be no significant differences between the means and the variances for females as compared to males, this does not completely describe the situation which was found to exist in 1954. No matter what limits one might set as denoting the normal limits of amplitude, there would be more females beyond these limits in both directions than there would be males. The range in 1954 for females extended from 2.75 D. to 11.50 D. while that for males extended from 4.25 D. to 10.00 D.

Another factor which should be pointed out here and which makes

the interpretation of the data difficult is that there appears to be a difference between the examiners even though the basic training and procedures employed were identical. The mean amplitudes for all subjects found by the various examiners is shown below along with the percentage of females and males examined.

Examiner	Mean Amp.	Per Cent Females	Per Cent Males
A	6.42	28.9	60.5
B	8.00	24.7	17.3
C	5.21	25.8	7.4
D	7.53	10.3	12.3
E	8.21	10.3	2.5

It could very well be that the extreme distribution found for the females was largely due to the apparent tendency for examiners B and C to find high and low values, respectively. On the other hand, it could be that this tendency was due to chance distribution and the fact that examiner C saw nearly four times as many females as males. Actually, it would appear that both factors were operating. The best guess is that at measurements in the neighborhood of 6.00 D. that there would be a difference of at least 0.25 D. between B and C and a difference not greater than 1.00 D.

DYNAMIC SKIAMETRY

The gross dynamic finding obtained in 1934 is not available. The tables that we now have giving the 1934 data indicate the amount of extra convex lens power found in dynamic as compared to the subjective finding: in other words, the dynamic is given as an "add" to the subjective.

As noted above, strange distribution patterns sometimes appear. In the case of the female subjects, complete dynamic data are available on 42 subjects (82.3%) but for some reason, not known, the dynamic data were obtained on only 16 males (36.3%) in 1954. The means and standard deviations are recorded in Tables 1 and 2.

F.S.C. OR HETEROPHORIA FOR 40 CM. FIXATION DISTANCE

As mentioned above, the near heterophoria was calculated from the distance heterophoria, the interpupillary distance and the accommodative convergence. The means and standard deviations are given in Tables 1 and 2.

ACCOMMODATIVE CONVERGENCE

The measurements discussed in this section involve the total amount of the convergence associated with the supposed total change in accommodation. The means and standard deviations are given in Tables 1 and 2.

There are many schools of thought concerning the nature of this

relationship between accommodation and convergence, ranging from inverse to direct, from innate to acquired, and from real to accidental.[3] To a large degree the differences in opinion are really differences in semantics in regard to the meaning of such terms as "biologic constant," "error of measurement," "stimulus value" as opposed to "response value" of accommodation, and "significant." There is, however, one real difference of opinion with respect to the "innate" versus "acquired" ideas. This difference involves the idea that accommodative-convergence may be significantly altered by visual training. The "innate" school of thought generally believes that, while it is possible to show at least a temporary alteration in the measurement of accommodative-convergence, training for an alteration in this function does not really change the function. The only change is a variation in the response to the method of measurement. The "acquired" school of thought, on the other hand, believes that this function can be significantly altered.

The fact that there appears to be no change in the male subjects seems to strengthen the argument of those who tend to be followers of what can be termed the innate school. On the other hand, the change which occurred in females tends to strengthen the opposing viewpoint.

If training can be effective in altering this function, it could be argued that the constant maintenance of single binocular vision should alter the function of accommodative convergence toward "normalcy." If, by accident, the function is high, it should diminish; if low, it should increase. In the case of the females, the interpupillary distance in 1934 had a mean value of just under 60 mm. Thus, the mean convergence required to bifixate a point 40 cms. from the eyes would be 15.0Δ. For purposes of analysis, it was assumed that any accommodative-convergence 15Δ or greater, was high. The low amount was arbitrarily selected at the mean minus one standard deviation.

There were ten females with an accommodative-convergence of 15Δ or more in 1934. The mean value was 17.4Δ for this group. In 1954 the same group had a mean value of 13.1Δ or a decrease of 4.3Δ. This change is significant at the 1% level of confidence.

There were seven females with an accommodative-convergence of 8.2Δ or less. In 1934 the mean for this group was 6.1Δ. In 1954 the mean for this group had increased by 3.7Δ to 9.8Δ. This difference is significant at slightly above the 5% level of confidence.

These calculations would indicate that there is a tendency for the high values to decrease and perhaps a tendency for the low values to increase. The additional qualification must be added that these changes were observed only in females. Unfortunately, these changes

in both females and males tend to add fuel to the debate mentioned above, rather than to settle the issue. For example, the question as to the accuracy of accommodation and the change with age cannot be answered.

The phenomena of the regression of measurements toward the mean would lead one to expect just such a change as that reported above. The mere fact that the mean value in 1934 was less than 15Δ and that it became even less in 1954, would argue that use did not tend to change accommodative-convergence in a desirable direction. Consequently, it is very difficult to believe that this apparent change in the function of accommodative-convergence is due to the use of the eyes.

This apparent decrease in accommodative convergence as measured by the "heterophoria method" employed here has been noted by Alpern and Hirsch.[4] The change reported by Alpern and Hirsch for clinical subjects of both sexes was from a value of approximately 15Δ for subjects age 13 to approximately 11Δ for subjects age 33.

MALE-FEMALE DIFFERENCES

The difference in the means of the various measurements between females and males was tested by the t test. The results are shown in Table III.

COMPARISON OF MEAN VALUES, FEMALE - MALE
TABLE III

Difference, mean female - male significant TEST	1934	1954
P.D.	–	S
Ophth. Cyl.	S	S
Rx Cyl.	–	S
Rx 180°	S	S
Rx 90°	S	S
Phoria	–	–
Add.	–	–
Abd.	S	S
Dynamic	S	–
F.S.C.	–	–
Ac.-Conv.	–	–
Amplitude	–	–

S—significant difference between the means of the tests on females as compared to males. A difference as great as that observed would be expected, by chance, no more than 5% of the time.

It is interesting to speculate that perhaps the reason for the difference in the abduction finding, which is significantly higher in females, is due to some tendency to put too much minus lens power on females. This would tend to agree with the general finding that the females are

more myopic than the males. It is difficult, however, to understand how this could come about both in 1934 and 1954. Perhaps females as a whole are more critical and demand better resolution for distant targets. This, of course, does not account for the change in the vertical meridian as indicated by both the ophthalmometer and the correction cylinder. Neither of these assumptions are confirmed by any significant difference in the phoria.

This greater change for females appears to be a continuation of the trend noted by Hirsch.[1] In order to obtain a direct comparison with the data of Hirsch, the spherical equivalent should be known. This can be obtained by approximation from the data given in Table 1. If the error in both the 180° and 90° meridians is added and the result divided by two, the resultant will closely approximate the spherical equivalent. Thus in 1934 the spherical equivalent for the females was +0.09 D. which is about 0.25 D. more myopic than that reported by Hirsch for 13-year-old girls. When it is considered that Hirsch reported on skiametric data and this report is based on subjective refraction, such a difference is not unexpected. The spherical equivalent for males aged 13 found in this study was just under +0.40 D. This is about 0.05 D. less plus than that reported by Hirsch for the same age. All in all, there does not seem to be a significant difference between the sample studied in this report and the 13-year-olds reported on by Hirsch.

As already mentioned, the trend for the changes in refraction from ages five to 14 continues from the ages 13 to 33, as far as the mean refraction is concerned. The mean refractive error for both males and females becomes slightly more myopic and there is an increase in the variance, the changes in females being greater than those in males. This gradual decrease in the hypermetropia does not mean that all individuals become more myopic or that even most of them do. The truth of the matter is that most individuals change very little during this period but some become markedly more myopic and in some cases there is an increase in the hypermetropia.

If the medians are used rather than the means, since this is value less influenced by extremes, the change in the females is from +0.25 D. spherical equivalent in 1934 to +0.20 D. in 1954. In the males, on the basis of the median, the change actually reverses: since in 1934 the median was +0.15 D. and in 1954, +0.55 D. If a change in refraction is arbitrarily chosen as being 0.75 D., 17 females became more myopic, 13 more hypermetropic, and 21 did not change. In the case of the males, 11 became more myopic, 10 more hypermetropic and

23 did not change. If the limit for a change is reduced to a 0.25 D., the percentage of distribution would be nearly the same.

ADDITIONAL COMMENTS ON CHANGE IN REFRACTION OF FEMALES

Since the changes in refraction were more marked in the females than the males, certain additional statistics were investigated for female subjects.

Nine of the 17 females who became more myopic had an increase toward myopia greater than the mean, minus one standard deviation and seven of the 13 females who became more hypermetropic had an increase greater than the mean, plus one standard deviation. Seven of the nine females who changed toward myopia were actually myopic in 1954 and all seven who changed toward hypermetropia were actually hypermetropic.

The tendency for some individuals to become more myopic has been the concern of both investigators and clinicians for many years. This change is real and is assumed to be associated with abnormal growth of the eye in which there is a relatively larger increase in the axial length of the eye than there is for the other factors determining refractive error (corneal curves, depth anterior chamber, curvature of the lens and index of refraction). This is independent of whatever factors might have induced this growth. There are a few who seem to believe that accommodation (lens curvature) is responsible but most conceive of the final change as being physical rather than physiological although it might be initiated by a physiological response.

On the other hand, most clinicians seem to feel that if there is an increase in hypermetropia it is due solely to latent hypermetropia becoming manifest. This conclusion seems to be brought about by the known reality of latent hypermetropia and the difficulty of conceiving of a decrease in corneal power or a decrease in axial length of the eye. It should be pointed out that if an eye just grows bigger, the cornea might become flatter. An increase in hypermetropia would also occur if there was an increase in the relative depth of the anterior chamber or a relative change in the index of refraction of the various media. An increase in hypermetropia is not always due to physiological rather than physical changes.

The mean values for the various measurements for these myopic and hypermetropic females, as found in 1934, were determined in order to see if there was any way by which these females who subsequently showed significant changes in their refractive error might have been identified prior to the onset of the changes. The following table gives the results obtained along with that obtained for all of the females.

(Group) Test	P.D.	Ophth.	Rx Cyl.	Mean Error	Phoria	Add	Abd	Amp	Dyn	PSC	Ac-C
Group as whole	59.7	+0.00	—0.14	+0.00	+0.8	13.6	8.8	11.96	+1.00	—1.6	12.4
Myopic	*57.7	+0.55	+0.14	*—1.625	*—2.1	16.7	8.6	11.70	+1.66	—0.9	*15.7
Hyper-metropic	60.5	+0.81	+0.06	+0.71	+2.2	15.0	9.7	11.16	+1.00	—1.1	11.8

*Difference Significant (5%)

None of the apparent differences between the hypermetropic subjects and the group as a whole is significant at the 5% level of confidence. For the myopic subjects it would appear that the interpupillary distance is smaller, the mean refractive error more myopic, the heterophoria more exophoric and the accommodative-convergence higher than for the group as a whole. (5% confidence level.) Thus, on the whole, the female subjects who became more myopic in twenty years than the mean minus one standard deviation of the refraction change, were already myopic at age 13. The exophoria for the group was higher than average and the accommodative-convergence was higher so that the phoria at near was not significantly different than for all of the 13-year-old female students.

Perhaps it might be well to emphasize that these differences are characteristics of the mean values for a group and not characteristics of each of the individuals in the group. Consequently, the data offer no more than the vaguest sort of a hint as to characteristics which might point out to the optometrist those particular adolescent females who might become myopic with age. The only statement which can be made about the group which would also be true for each of the individuals is that they were not hypermetropic in 1934.

Frequently, myopia appears to be associated with abnormal growth. One might suppose the P.D. to be related to body size and thus, that the small mean P.D. would increase as the subjects became older and more myopic. The P.D. of this group of myopic subjects had a mean value of 60.7 mm. in 1954. This is still smaller than the mean for the group as a whole at the 5% level of confidence. The change for the myopic females was 3.0 mm. while that for the females as a whole was 3.1 mm.

GENERAL COMMENTS

The changes in the mean value for the various measurements made is very small. Some better idea of these changes can be appreciated from the following observations dealing with the changes in refractive error.

It might be concluded from this that the number of individuals in the general population of age 33 needing correction lenses would be

Changes	±0.25 D. or less	+0.75 D. or more	—0.75 D. or more
180° female	41%	12%	21%
180° male	52%	12%	12%
90° female	32%	17%	28%
90° male	52%	14%	14%

relatively small. This is not necessarily the case, since, as has already been emphasized, there has been an increase in the dispersion of the refractive error. This seems to be a continuation of the process noted by Hirsch in his cross-section study of school children.

Some of the individuals examined in 1954 were given their first pair of correction lenses. Most of those needing lenses had already obtained and were wearing them. In the table below, no distinction will be made as to how long the individual had worn lenses. Only two criteria were used in selecting these subjects: (1) The subject had lenses which he wore, (2) The symptoms and the refractive error justified the need for lenses. The need for reading lenses or other care was not considered.

FEMALES WEARING LENSES IN 1954

Reason	Number	Per Cent of Group
Myopia	7	13.7%
Hypermetropia	7	13.7%
Astigmatism[1]	9	17.6%
Unknown[2]	1	.2%
Needed but not[3]	1	.2%
	Total	47.1%

MALES WEARING LENSES IN 1954

Myopia	3	6.8%
Hypermetropia	4	9.1%
Astigmatism[1]	2	4.5%
Unknown[2]	2	4.5%
Needed but not[3]	3	6.8%
Special purpose[4]	1	2.3%
	Total	25.0%

[1]Astigmatism was assumed to be the refractive error whenever the cylindrical correction was greater than twice the spherical portion.

[2]One female and two male subjects had lenses which they wore even though they had little or no refractive error and no symptoms.

[3]One female and three males had visual symptoms and fairly large uncorrected errors of refraction but they would not consider wearing lenses.

[4]One of the male subjects was a dentist and he wore lenses for the sole purpose of protecting his eyes from flying particles.

As far as the present writer is aware, there has not been any longitudinal study of changes in refractive error on a nonselected sample other than the one reported here. The chief problem has been in obtaining a

satisfactory sample. If clinical data could be used, longitudinal studies could easily be made. In order to get some idea as to the comparison between the group reported on here and clinical subjects, the records of the author's private practice were employed.

The method of selection was to start through the files beginning with those patients whose name began with the letter A. The subjective refraction of every female and male subject between the ages of 30 and 35, was noted. This was continued until the data of 50 female patients had been recorded. In the same number of records used, there were 35 males. Every record was used whether lenses had or had not been prescribed for that particular patient.

The same number of records was investigated rather than searching for equal numbers of female and male patients in order to see whether the same tendency, noted above, for more females to have refractive errors than males was true for clinical patients. The assumption was made that the need for visual care is probably related to the seeking of visual care. The conclusion based on the study group that a larger percentage of women need refractive care than men seems to be borne out.

The mean and standard deviation of the subjective correction for the females in this clinical group was +0.22 D. ±1.71 D. in the 180° and 0.00 ±1.71 D. in the 90° meridian. For the males the results were +0.11 D. ±1.75 D. in the 180° meridian and —0.46 D. ±2.20 D. in the 90° meridian. The difference in the means for these female and male patients is not significant.

The mean values for the clinical and study subjects were compared. The only significant difference in the mean values was that for the 90° meridian in male subjects. The increase in the variance for the female patients for the 180° meridian is barely significant: the change of variance for the 90° meridian is not significant. The difference in the variance for the male patients, as compared to the male subjects, is highly significant.

The total range of refractive error on the basis of equivalent sphere was for the female patients from —5.50 D. to +7.25 D., while for the female subjects it was from —6.38 D. to +2.25 D. For the male patients the range was from —6.75 D. to +8.25 D., while for the male subjects it was from —3.75 D. to +2.25 D.

It would seem then that at this age level the chief difference in the refractive error between female patients and a nonvisually selected sample of the female population is the range of errors. The differences between male patients and a nonvisually selected sample of the male population

are much greater.

The data we have indicate that with the aging process there is a gradual increase in the variance of refractive errors from ages 6 to 33, at least. There is a gradual increase in the percentage of those requiring visual care so that in time the difference between a clinical sample and a sample of the general population would tend to disappear. Thus, if refractive changes in children are to be studied, it is important to use a nonselected sample. On the other hand, if refractive changes in elderly people are to be studied, a clinical sample might be just as satisfactory as a nonvisually selected sample.

It is hoped that correlation studies can be made in the future of various vision functions and other physical and psychological factors.

SUMMARY

The means, standard deviations and correlation coefficients for a nonvisually selected sample first examined in 1934 (age 13) and again in 1954 (age 33) have been determined. For the female subjects significant changes (5% level) occurred in the mean value of: P.D.; corneal astigmatism; correction cylinder; refractive error in the vertical meridian; base-in vergence; amplitude of accommodation; heterophoria at 40 cms. and accommodative-convergence. For the male subjects significant changes occurred in the mean value of P.D.; corneal astigmatism; base-out vergence; amplitude of accommodation; dynamic skiametry, and heterophoria at 40 cms. In 1934 there was a significant difference between females and males in: corneal astimatism; correction in the horizontal meridian; correction in the 90° meridian; base-in vergence, and dynamic. In 1954 a significant difference between females and males was found in: P.D.; corneal astigmatism; correction cylinder; refraction in the horizontal and vertical meridians, and the base-in vergence.

The mean refractive error became about 0.04 D. more myopic for the males during this 20-year period from ages 13 to 33, while it became about 0.22 D. more myopic for the females. Approximately 25% of the males needed a lens correction at age 33 while more than 50% of the females required correction.

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THE OPTICS OF MAGNIFYING SUBNORMAL VISION DEVICES*

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When the optical properties of an eye cannot be altered by ordinary corrective means to provide adequate vision it becomes necessary to employ some method of increasing the size of the retinal image.

There are essentially three different methods for increasing the angular size of the retinal image of an object. The commonest method is decreasing the distance of the object from the eye. This method is available to anyone with sufficient accommodation and is widely used by infants and small children. The second method necessitates that the object itself be enlarged. For example, in place of 10 point type in a book, larger size type of 18 or even 24 point might be used. This method has been extensively and successfully employed in the elementary school classrooms. The third method necessitates the use of one or more lenses in front of the eye to produce angular magnification.

Relative Distance Magnification. Everyone is acquainted with the important role of distance in visual resolution. The difficulty in reading street and bus signs at relatively long distances is a typical example. With a reduction of the distance, of course resolution becomes easier.

In order to evaluate the relative effectiveness of distance on visual resolution it is necessary to use some distance as a standard reference. Although this actually could be any distance, 40 cms. or the average near working distance is most preferable. By the use of this standard, the angular size of the object at any distance, p, relative to its size at 40 cms. easily can be computed. This ratio will be called relative distance magnification and is designated as M_d.

If a_1 is the angular size of an object at a distance of p, and a_2 is the angular size at 40 cms. as shown in Figure 1, it follows that

$$M_d = \frac{\tan a_1}{\tan a_2} = \frac{40}{p} \qquad (1)$$

The size of M_d for various values of p is shown in Figure 2. In this

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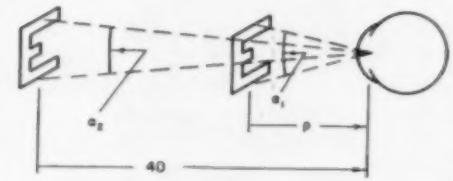

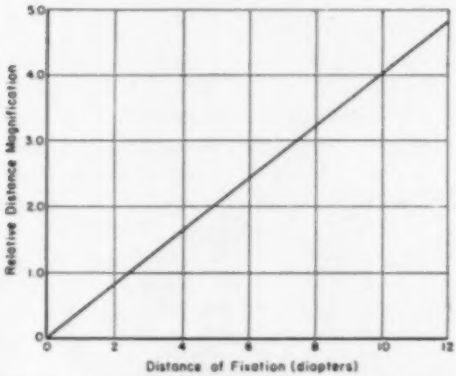

Fig. 1. (Top) Schema for computing relative distance magnification.
Fig. 2. (Bottom) The variation of relative distance magnification with the distance of fixation. For reference, a distance of fixation of 40 cms., i.e. 2.5 D. is employed.

figure, the ordinate is the relative distance magnification and the abscissa is the reciprocal of p measured in meters, i.e., the distance of fixation in diopters. It should be noted that the relative distance magnification is unity, that is one for a distance of fixation of 2.5 diopters, or 40 cms. For shorter distances than 40 cms., the magnification markedly increases; for larger distances, it decreases.

The very important role of distance magnification now should be evident. Relative to a distance of 6 meters, a viewing distance of 3 meters would have to be employed to obtain a magnification of 2X. Relative to 40 cms., however, the viewing distance needs to be changed only to 10 cms. to obtain 4X.

Compensation for Inadequate Accommodation. With sufficient accommodation, the full benefit of relative distance magnification can be obtained; without it, the decrease in visual acuity due to out of focus imagery more than offsets the gain due to proximity. The effects due to both factors are shown in Figure 3 for comparison. In the top graph, the magnification required to compensate for the blurredness of

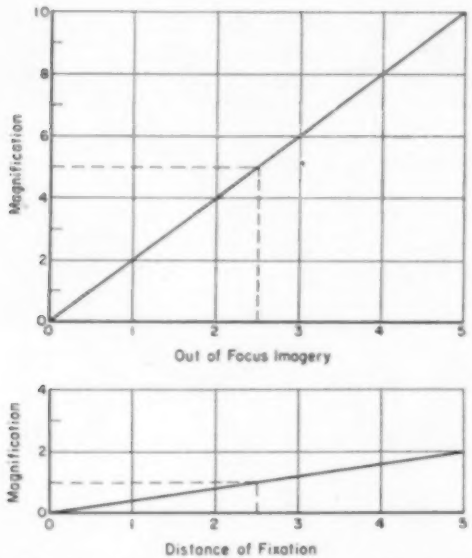

Fig. 3. (Top) The magnification required to compensate for out of focus imagery. (Bottom) Relative distance magnification obtained by variation of the distance of fixation. The abscissa for both graphs is in diopters.

the retinal image due to out of focus imagery is provided: it is seen that approximately 2X magnification is needed per diopter of out of focus imagery. Thus, if an individual had 20/20 vision at distance and no accommodation, 5X magnification would be needed at 0.40 M. to obtain the equivalent distance acuity.

The lower graph in Figure 3 shows the relative size magnification. It is apparent that the relative size magnification falls far short of compensating for the blurredness due to out of focus imagery.

The importance of relative size magnification and out of focus imagery cannot be overstressed. Under no circumstances should the assumption ever be made that an individual has sufficient accommodation on the basis of age. Experimental evidence clearly indicates that such an assumption oftentimes deprives an individual of one of the simplest and most readily usable methods of securing a necessary enlargement of the retinal image for adequate vision.

Relative Size Magnification. It is a common experience for individuals with subnormal vision to report that the only print in a newspaper that can be seen are the headlines. Also, a visual acuity of 20/200, for example, signifies that if the test letters of the acuity chart

are ten times larger than those for 20/20, they can be seen. These two instances illustrate the value of increasing the actual size of an object for visual resolution.

Obviously, it is not possible to increase the actual size of everything to be used by a person with impaired vision. However, it is possible to obtain needles in different sizes. If one desires to sew and a needle of regular size cannot be used due to difficulty of threading, etc., then a needle of larger size is indicated. Similarly, the problem of reading can be met. Here, however, the major problem is that textbook material for school children and other reading material in large size type is very limited. Even so, it does represent one of the chief methods of increasing the size of the retinal image, and one that has been extensively and successfully used in sight saving classes.

Textbooks for schoolroom use, newspapers and magazines, usually are printed in 8 to 12 point type. The point system is simply a method according to which the various sizes of type bodies, and leads, bear a fixed and simple relation to one another. The point system is based upon the pica body. This body is divided into twelfths, called "points" and every type body consists of a given number of these points. The value of the point is 0.0138 inch, or nearly 1/72 inch.

Since visual acuity frequently is specified by angular measure, the angular size of letters of different size type are given in Figure 4. It is seen that 10 point type subtends a visual angle of 0.5° or 30′ at a distance of 40 cms. from the eyes. Consequently these letters are 6 times larger than the minimum resolveable for 20/20 visual acuity.

In order to specify the relative magnification due to the use of print of large size, a standard of 10 point type is used. The relative size magnification, then, can be defined as

$$M_s = \frac{\tan \alpha_1}{\tan \alpha_2} \qquad (2)$$

where tan α_2 is the angular size of 10 point type and tan α_1 is the angular size of enlarged type. This relation is illustrated in Figure 5. Obviously, it is not necessary to specify any specific reading distance in this definition, since the type of both sizes will vary equally for different distances. For any given case, however, the same distance of fixation must be used for both sizes of type.

Opaque Magnification. When an enlarged image of an opaque object is produced on a screen the method is called opaque magnification. Usually, some form of optical projection device has to be employed, and then, as a rule, the image is formed on a translucent screen.

If an opaque magnifier is used for print of normal size, the effect

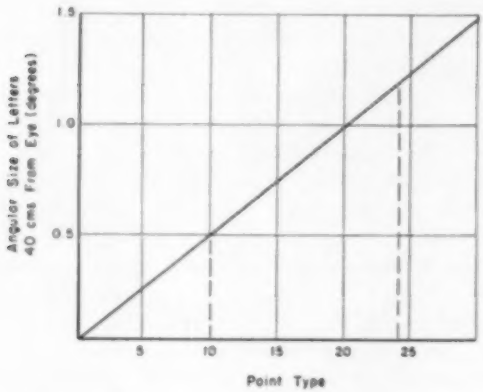

Fig. 4. (Top) Specification of the angular size of print of different point type at a reading distance of 40 cms.
Fig. 5. (Bottom) Schema for computing the relative size magnification.

is the same as if it were of large size type. Also, with both methods the observer has complete freedom in the choice of the reading distance. For these reasons, the enlargement of the image obtained by the use of opaque magnifiers will be called relative size magnification.

Recent advances. Recently, the American Optical Company announced the availability of a new opaque magnifier for subnormal vision. This represents the culmination of over ten years of effort by a large number of cooperating agencies and organizations better to meet the needs of individuals with this type of visual impairment.

The optical principle of the magnifier is shown in Figure 6. It is seen that the image undergoes double reflection. By this means the image on the screen is oriented in the same direction as the object both vertically and horizontally. For movement of the image on the screen, the object to be enlarged is changed in position by adjustment of the platform or carriage for the object. The screen is ground acetate and made in the form of a Fresnel lens. The focus for the lens is directly in front of the screen. By this means the image has maximum contrast with a minimum loss of light.

The magnifier comes in two powers, namely: 3X and 5X. For

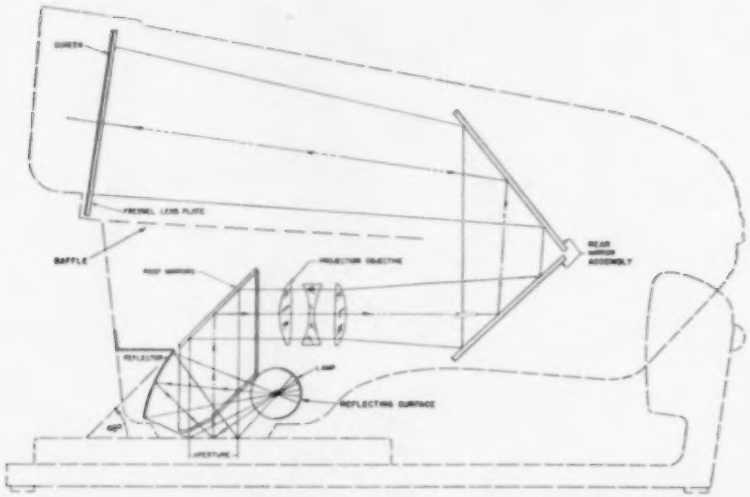

Fig. 6. Cross section of the AO projection magnifier illustrating the essential optical components. Only the projection lens and one pair of mirrors is adjustable.

both powers, the same housing and optical components are used and the only difference is the adjustment of the projection lens and one pair of mirrors. The principle involved is shown in Figure 7.

Another projection magnifier is known as the megascope. It is shown in Figure 8. With it, magnifications of either 12.5X or 25X can be obtained by use of interchangeable optical systems. The instrument is available from the American Foundation for the Blind.

Combined Effects. The magnification available from either relative size or distance magnification is limited. For example, it is not practical to print a book in print larger than 24 point type. In comparison to 10 point type, the linear magnification is 2.4X. However, it must be remembered that in area, the increase is the square of the magnification. For the example cited above it is $(2.4)^2$ or 5.74X. Thus, an average book printed in 10 point type on 6 $\times$ 9 inch format and, for example, 300 pages in length, would require 300 $\times$ 5.74 or 1,722 pages of the same size paper in 24 point type: this would amount to 6 volumes of 300 pages each. In addition to the obvious disadvantage of number of books, perhaps an even more serious problem is the financial one. With limited editions, the cost of necessity has to be greater. For these and other reasons most books especially printed for the partially sighted do not exceed 18 point. For this size of type, M_s = 1.8X.

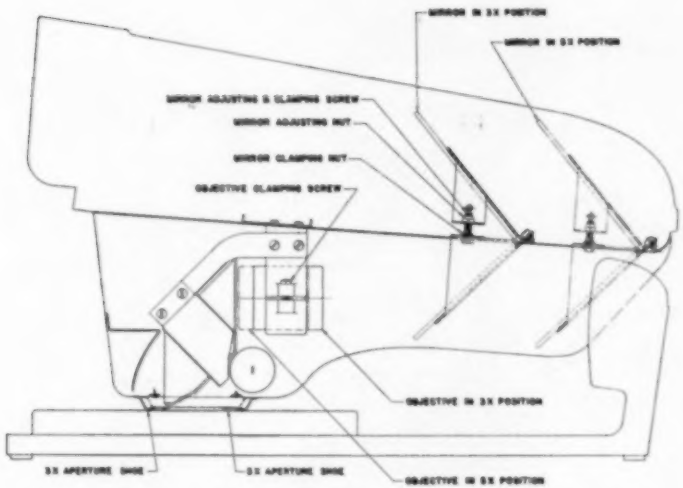

Fig. 7. The relative positions of the rear mirror assembly for 3 X and 5 X magnifications.

Fortunately, there is no optical limit for M_s by opaque magnification. At the present time opaque magnifiers, specifically designed for subnormal vision, are available in powers of 3X, 5X, 12.5X and 25X. In order to obtain these magnifications, however, an optical instrument must be used. This can constitute a serious drawback but not necessarily a greater one than the purchase of books printed in large size type. It will be seen that in combination with (M_d) the results with opaque magnifiers are very desirable.

The enlargement of the retinal image by relative distance magnification also is markedly restrictive. Very short reading distances require large amounts of accommodation as well as reasonably quick changes in the power of the eye to maintain clear vision for small changes of the reading distance. With binocular vision, the problem becomes even more difficult due to possible difficulties in maintaining convergence. With normal vision these tasks are difficult: with subnormal vision there is little wonder why they oftentimes become impossible. For these reasons, the practical limit of (M_d) is 4X. For this advantage the reading distance has to be 10 cms.

Although each type of magnification alone is relatively ineffective, in combination they produce very desirable results. In order to illustrate these effects, let

$$(M_t) = (M_s)\ (M_d).$$

Fig. 8. A photograph of the megascope. The book is printed in 10 point type and the image on the screen is magnified 25 X.

Also, the assumption will be made that an individual must have at least 20/40 visual acuity to read 10 point type.

Case 1. $(M_s) = 2.4X$: $(M_d) = 1.6X$.

It follows that

$$(M_t) = (2.4)\ (1.6)$$
$$= 3.84X.$$

A magnification of this magnitude would be useful provided that the visual acuity was not less than 20/150. In order to obtain an M_s of 2.4X either a book printed in large size type or an opaque magnifier could be employed.

be employed.

Case 2. $(M_s) = 2.4X$: $(M_d) = 4.0X$.

Then

$$(M_t) = (2.4)\ (4.0)$$
$$= 10.6X.$$

This amount of magnification would be sufficient for reading with visual acuity as low as 20/400. It would necessitate the use of a very short reading distance, i.e., 10 cms.

Case 3. $(M_s) = 5.0$: $(M_d) = 2.0$

Substituting

$$(M_t) = (5.0)\ (2.0)$$
$$= 10X.$$

This case is similar to Case #2. In this instance an opaque magnifier would be necessary to obtain (M_a).

Case 4. $(M_a) = 12.5$; $(M_d) = 2.0$.

It is seen that

$$(M_t) = (12.5)\ (2.0)$$
$$= 25X.$$

A magnification of 12.5X only could be obtained with an opaque magnifier. Also, 25X represents the practical upper limit of magnification for reading. It will permit reading with a visual acuity of only 20/1000.

Case 5. $(M_a) = 25.0$; $(M_d) = 1.0$.

Then

$$(M_t) = (25.0)\ (1.0)$$
$$= 25X.$$

This example was included merely to show another useful method of reaching the practical limit of magnification. As in Cases 3 and 4, only an opaque magnifier could suffice for (M_a).

Up to this point the report has been limited to only methods utilizing real objects for enlargement of the retinal image. As pointed out at the outset, in addition to size and distance magnification, angular magnification also can be used. This always requires the use of a virtual object.

The only optical aid for obtaining angular magnification at distance is the telescope. For near distances, magnifying spectacles, loupes and reading lenses are available. In a second portion of this report these aids will be reviewed.

ANNOUNCEMENT

LOS ANGELES COLLEGE OF OPTOMETRY NAMES DEAN

Announcement from the Board of Trustees of the Los Angeles College of Optometry on May 26 named Charles A. Abel, O.D., Dean of the College effective immediately. Dr. Abel has been a member of the college faculty and administration since 1950, having served as instructor, Clinic Director, Acting Dean, and Administrative Assistant.

COMPARISON OF HIGH ACUITY SCORES ON SNELLEN AND ORTHO-RATER TESTS*

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U. S. Naval Medical Research Laboratory
U. S. Naval Submarine Base
New London, Connecticut

Visual acuity involves the ability of the eye to discriminate contours as measured by the size of the target item. Since contours can take many forms, it is to be expected that differently shaped contours will yield different values of acuity from the same individual. Evidence of this has been found in many studies, among which the AGO "Studies in Visual Acuity"[1] indicates from the factor analysis that a test may involve as many as four factors: retinal resolution, brightness discrimination, simple form perception, and letter perception. Of these, retinal resolution accounts for most of the variance in test scores and is the primary factor considered in visual acuity measurements. While size is paramount, the indication is that the same item size is not equivalent from one contour to another.

The most widely used acuity test is the Snellen letter chart. This term is loosely applied to any chart of capital letters printed in graded sizes, and several companies offer carefully prepared charts, any one of which is accepted as standard. In principle, the Snellen letter chart is based on a five by five checkerboard square. For example, the E stroke width and the separation of strokes are the same, but when other letters are drawn within a square, the basic premise cannot be maintained, Figure 1. This results in an inequality of the individual test items and subverts the original intent of the letter chart. Nevertheless, clinicians use the charts almost exclusively because most patients are familiar with the task of reading. The factor analysis in the AGO study confirms the high level of retinal resolution in the Snellen test but shows considerable contamination by the letter factor.

In recent years, the checkerboard target has gained in usage through its incorporation in acuity testing devices such as the Bausch and Lomb ortho-rater. Such tests do not depend on literacy and the AGO analysis indicates that the checkerboard target has the highest retinal resolution

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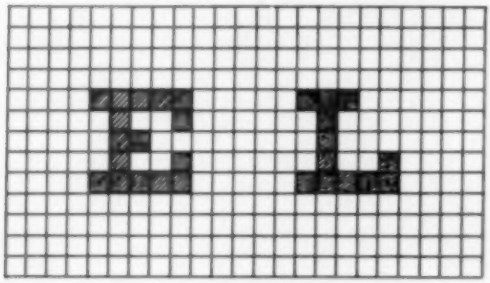

Fig. 1. Block principle of Snellen letters.

factor of any present test, without significant contamination by other factors.

When scores from the Snellen charts and from the ortho-rater have been compared, it has been assumed that identical width of stroke of a letter and size of checker give equal measures of visual acuity. However, since these are radically different contours and have different factors, it should not be expected that their equivalence will be based on equal size. A comparison of the tests was undertaken to determine their size relationship and to set up a transformation equation of acuity score from one test to the other.

METHODS AND PROCEDURE

Test Conditions: The letter test was given in a vision alley painted and illuminated in conformity with the standards set by the Army-Navy NRC Vision Committee.[2] Brightness of the chart averaged 14.0 footlamberts with readings of 15.5 and 12.5 ft.-L from top to bottom, respectively.

Targets: Three American Optical Company Snellen wall charts, No. 1930, were used interchangeably. For variation, while retaining equal difficulty, the letters were cut out, rearranged and reset in their proper lines. The marks of these alterations were not visible at 20 feet. Monocular testing was obtained with the use of a flat opaque occluder.

A commercial Bausch and Lomb ortho-rater was used for checkerboard monocular distance acuity measures.

Scoring: The Snellen score recorded was the smallest line read correctly allowing one error. Ortho-rater score was the last correct report of the checkerboard position followed by two consecutive errors.

Subjects: A total of 1,071 scores in each of the two tests was obtained from men in the submarine service during a visual screening of the personnel of fifteen boats.

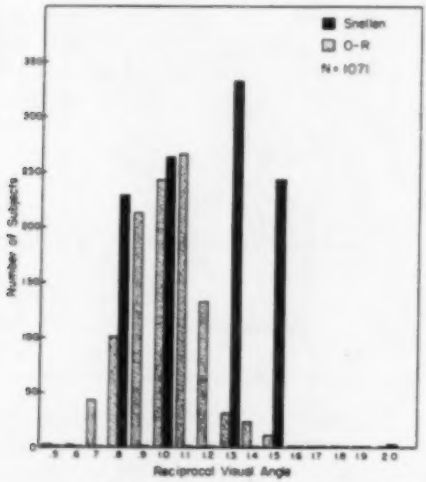

Fig. 2. Frequency distribution of Snellen and ortho-rater high acuity scores from an unselected submarine population.

RESULTS

Two histograms were drawn on the same base line in Figure 2 showing the distribution of Snellen and of ortho-rater scores. The placement of both the Snellen and ortho-rater scores on the abscissa is at the equivalent reciprocal visual angle for stroke of letter and for size of checker. The reciprocal visual angle is used in this and other diagrams because visual resolutions will then plot in a straight line. The obvious difference between the distributions is that while the frequencies in each of the Snellen categories are substantially the same, ortho-rater scores approach a normal distribution. Very few resolution scores of 1.3 to 1.5 were found with the ortho-rater whereas the Snellen test gave a high frequency at 20/15 and 20/13, the so-called equivalents.

Replotting the data in a scattergram, Figure 3, helps to bring the differences into better focus. The plotting is in the same units as the previous diagram, i.e., reciprocal visual angle.

It was suspected that the regression line of y on x was not linear so a test was made by finding *eta* (0.5754), the correlation ratio, and comparing it to *r* (0.5517), the coefficient of correlation. Since *eta* was found to be significantly larger than *r* at the 1% level of significance, the regression line of y on x is a nonlinear function.

DISCUSSION

An examination of Figure 3 shows that the increase in resolution

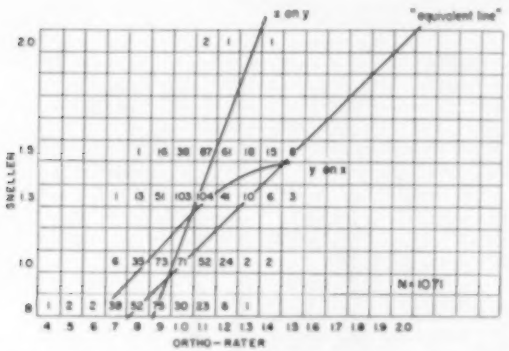

Fig. 3. Scattergram and regression lines of Snellen and ortho-rater high acuity scores.

is not as rapid as the increase in Snellen score would lead one to believe. These differences must be due primarily to the letter factor which results in the high Snellen "acuity" scores without corresponding increase in resolution. This is evident because a score of 20/10 which should indicate twice as good an acuity as 20/20 and therefore a resolution score in the ortho-rater of 20 (2.0 reciprocal visual angle) gives a score of only 12 (1.2 reciprocal visual angle). This means that the subject cannot see "twice as well" in the case of 20/10, but that he has learned to utilize the additional cues. Similarly 20/13 and 20/15 indicate ortho-rater scores of 15 and 13 respectively (1.5 and 1.3 reciprocal visual angle).

Unfortunately, the idea that 20/10 means a man's vision is twice as good as that of a man with 20/20 is carried to other visual tasks, when in reality his retinal resolution, the basic factor in acuity, is only perhaps 20 per cent better.

Table I lists the equivalent score when going from one test to

TABLE I

Conversion Scores from One Test to the Other

Ortho-Rater to Snellen		Snellen to Ortho-Rater	
7	20/25	20/25	9
8	20/22	20/20	10
9	20/20	20/15	11
10	20/17	20/13	11
11	20/15		
12	20/15		
13	20/14		
14	20/14		
15	20/13		

the other. Due to the nonlinearity of the regression line, the average score for the distribution within a category was used as the predictor.

It should be remembered that going from test A to test B is not the same as going from B to A. Therefore, an ortho-rater score of 15 predicts a Snellen score of 20/13 but a Snellen score of 20/13 predicts an ortho-rater score of 11. The regression lines in Figure 3 are drawn through the averages of the distribution in each direction and are thus the best predictive scores for each distribution.

SUMMARY

Evidence is presented showing that high Snellen scores are only moderately predictive of high ortho-rater scores and vice versa. This is attributed primarily to the letter factor which gives additional clues to resolution and prevents presumed equality of resolution of letter stroke and checker size. A new conversion for high scores on both tests is presented which is derived from testing a large population having high acuity.

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CORRESPONDENCE

AN OPTOMETRIC LOCATION IN WISCONSIN

To the Editor:

Thank you for your answer to my inquiry about an optometric tenant for the office space available in Thiensville, Wisconsin, which is bordered by the City of Mequon and both are just thirteen miles north from the center of Milwaukee. In 1950, the population was over 23,000, but since then, it has more than quadrupled.

The office space is in a one-floor office building known as the Ozaukee Medical Center. It is divided into four sections: one has five physicians, next is an insurance company, along side that is the dental area which is divided in half leaving this section suitable for an optometrist sharing the waiting room. On the other side, a chiropedist has an office. The building, which was built last year, is located on the Main Street, Highway 57 from Milwaukee, and has ample parking lots in the front and rear.

There is one optometrist in Cedarburg, seven miles north of Thiensville, leaving almost all of Ozaukee County and the northern suburbs of Milwaukee completely without an optometrist.

The office space will become available for occupancy after July 1st, when the remodeling will be completed. Anyone interested may contact me for further information or Mr. Harry J. Aronson, 4117 North Green Bay Avenue, Milwaukee, Wisconsin, FRanklin 2-6511, who will be glad to show them through the offices.

ROBERT M. ARONSON, D.D.S.

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THE MULTIPLE-PATTERN VISUAL FIELD SCREENER—AN EVALUATION*

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INTRODUCTION

The introduction of the Multiple-Pattern Visual Field Screener, or "Harrington-Flocks" screener, has been met by an enthusiastic welcome throughout the eye care field. Roberts[1] has found the screener to be a "highly useful new tool"; King[2] has said that the test is "a great advantage in visual field screening"; Vail[3] has pronounced it "excellent."

The widespread acceptance of this instrument has been partly due to the excellence of the screener itself, and partly due to the liberation that it offers from the tedium of standard perimetry. It has aided the busy practitioner more nearly to approach the ideal eye examination—one which would routinely include an evaluation of extrafoveal visual acuity. The inventor has made it quite clear, however, that this screener is just that, a screener, and is intended to supplement and not supplant standard quantitative perimetry.

Essentially, this method is a tachistoscopic presentation of extrafoveal stimuli from strategically located points within the central visual field, and an assessment of the patient's preception in terms of a number. A great advantage of the test is that it is a qualitative test, but the patient's response is stated in quantitative units.

The test is accomplished by having the patient view a series of ten cards, approximately 12"x18", upon which are printed a central black fixation dot and two or more symbols in white fluorescent ink critically placed within 25° of the fixation point. As each card is viewed in succession it is irradiated with ultra violet, "black," light for 0.25 second, which causes the fluorescent ink to become momentarily visible. The patient reports the number of symbols seen, and any that are missed are recorded on the provided chart. The test requires approximately 3 to 4 minutes for each patient.

REVIEW

Robertson[4] was the first to report an evaluation of the instrument in use in the field. In his series of 5,630 individuals 3.8% failed the

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†Military Optometrist.

test and were referred for further study. Of those referred there were 49 (24%) whose chart showed a recognizable "pattern" (e.g., hemianopia, sector defect, enlargement of the blind spot, etc.), and 166 (76%) who did not show a "pattern." Robertson did not report the number of over-referrals (those whose initial test could not be confirmed with standard perimetry), but his "initial impression" was that approximately 50% of the "nonpattern" group were over-referred. In discussing Robertson's paper Harrington referred to the survey that had been conducted by McGough in Alexandria, Virginia. McGough[5] reports a referral rate of 2% and an over-referral rate of 8.5% of those who failed the Harrington-Flocks test twice.

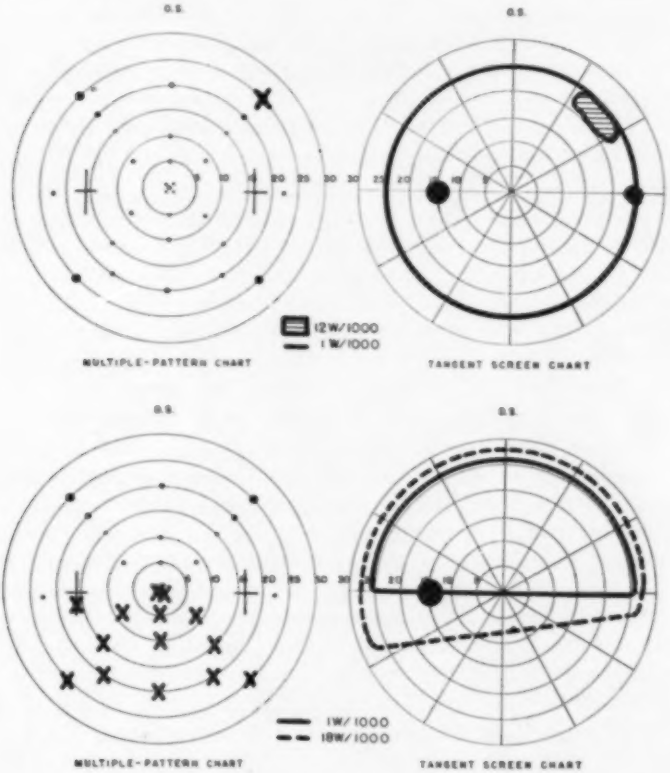


Fig. 1. (Top). Case No. 3, chorioretinitis, old.
Fig. 2. (Bottom) Case No. 16, optic atrophy, secondary to trauma of the optic nerve.

The routine use of the screener in the clinic for 1,433 patients was found by Roberts[1] to yield a referral rate of 6.5% and an over-referral rate of 42.5%. Roberts also reports the results for 107 patients with proven glaucoma, and this group had an under-referral rate (i.e., negative Multiple-Pattern test, but positive tangent screen test) of 9.3%, but he regarded these as "equivocal."

An additional use for the instrument has been suggested by Zugsmith.[6] The screener may be used as a magnetic tangent screen by employing a non-ferrous top painted with tangent screen circles on the back, a magnet, and the magnetic test objects of Conover and Spaeth.

An interesting note on the use of the screener with aphakics has been contributed by Sloan.[7] She points up the fact that the crystalline lens does not transmit the ultra violet, and therefore in the aphakic patient the filtering action of the removed lens must be supplied with a filter (Wratten No. 2A) if the patient is to see the test pattern as the phakic patient does. Without the filter there is insufficient contrast for the aphakic patient to respond correctly.

RESULTS

The present study is a report of a visual field survey of 607 individuals. The group was comprised of Army personnel and their dependents who presented themselves for examination at the U. S. Army Hospital, Camp Wolters, Texas. There were 19 (3.1%) who failed the test and were referred for a complete eye examination including a tangent screen study. Of the 19 referred patients there were three whose failure was not confirmed, yielding an over-referral rate of 15.8%. Data concerning the 16 patients with demonstrable visual field defects are presented in Table I.

An attempt to roughly quantify the intensity of the defect was made as follows. Any symbol that was missed twice by the patient was marked on the chart with an "x." The test card was thereupon illuminated with constant ultra violet, rather than a 0.25 second flash, and if the symbol in question was still unseen the "x" was circled. Subsequent examination on the tangent screen showed that any area of the field that had been marked with a "circled x" showed a rather dense defect (10w/1000 or greater) and the over-referral rate for this group was zero.

The only difficulty encountered was the rather critical positioning of the patient's head in order to have the physiological blind spot properly oriented. This can be overcome, however, by a few trial and error positionings of the patient's head.

TABLE 1
Patients with visual field defects as shown with the Multiple-Pattern Screener and the tangent screen

Patient's No. and Age	Visual Field Defect	Diagnosis
1. 28 years	Scotoma, right inferior temporal	Unknown
2. 20 years	Concentric contraction, O.S.	Dust-like opacities of the vitreous due to active posterior uveitis
3. 29 years	Scotoma, left superior, nasal	Chorioretinitis, old
4. 34 years	Concentric contraction, O. U.	Hysteria
5. 22 years	Para-central scotomata with enlargement of the blind spot, O.S.	Retinal hemorrhages, traumatic, old
6. 27 years	Central scotoma, O.S.	Central chorioretinitis, old
7. 49 years	Central scotoma, O.S.	Disciform degeneration of the macula
8. 29 years	Scotoma, left inferior, temporal	Unknown
9. 30 years	Central scotoma, O.S.	Contusion injury of macula, old
10. 42 years	Scotoma, left inferior, nasal	Unknown
11. 60 years	Nerve fiber bundle defect, O.S.	Glaucoma
12. 31 years	Central scotoma, O.D.	Contusion injury of macula, old
13. 23 years	Concentric contraction, O.U.	Congenital night blindness
14. 41 years	Enlargement of the blind spot, and concentric contraction, O.U.	Medulated nerve fibers at the discs, and congenital night blindness
15. 34 years	Concentric contraction, O.U.	Functional
16. 30 years	Altitudinal hemianopia, inferior, O.S.	Optic atrophy, secondary to trauma of the optic nerve

From the cases disclosed in this series five have been selected to exemplify the use of the test, and a comparison of the Harrington-Flocks test and tangent screen test is presented. See Figures 1 to 5.

DISCUSSION

Regarding the problem of over-referral, the "less than 2%" over-referral rate that Harrington and Flocks[8] found in their series of about 600 individuals (age 65 or less) is somewhat lower than that reported in four subsequent series. See Table 2 for a recapitulation.

TABLE 2
Comparative rates using the Multiple-Pattern Visual Field Screener

Series	N	Referral rate, %	Over-referral rate, %
Harrington & Flocks	>600	—	<2
Robertson	5,630	3.8	39*
McGough**	4,968	2.0	8.5
Roberts	1,433	6.5	42.5
Present Study	607	3.1	15.8

* "initial impression"
** referral criterion: fail test twice

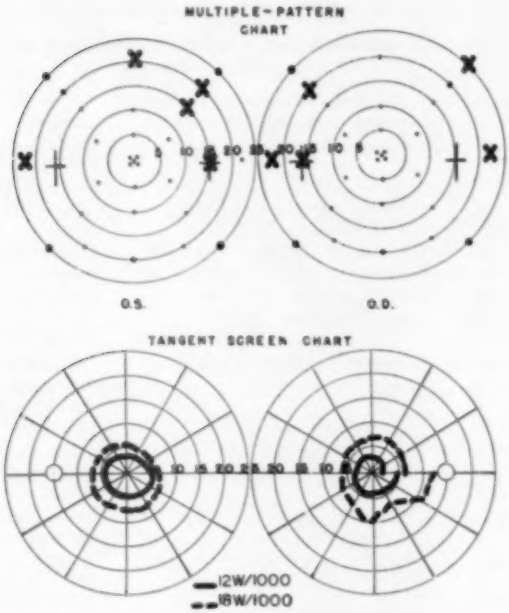


Fig. 3. Case No. 4, hysteria.

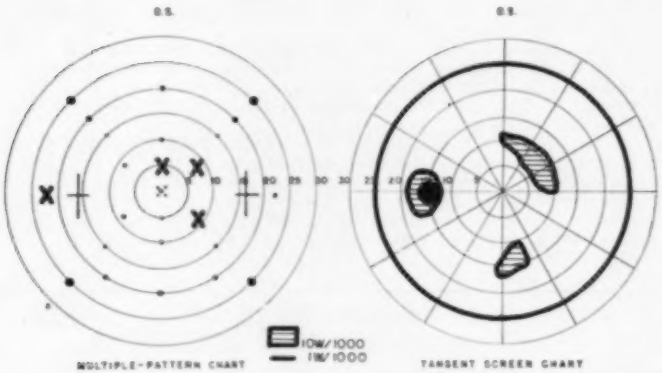
One explanation for the lower over-referral rate in the Harrington and Flocks series may be that almost half of their "normal" group were highly intelligent trained observers—physicians.

Roberts is the only author who has offered statistics on the critical question of the under-referral rate—his previously mentioned "equivocal" 9.3%. Harrington and Flocks reported an under-referral of five patients. Their defects were, however, "in most instances," considered to be "minimal." Further elucidation of the under-referral problem would certainly be of value, because in terms of public health, the under-referral rate is certainly of greater importance than the over-referral rate. A moderate over-referral rate may be regarded as a good thing, a margin of safety, but under-referrals tend to provide the patient with a false sense of security.

SUMMARY

The Harrington-Flocks Multiple-Pattern Visual Field Screener is described, and its place in the eye care field acknowledged.

The results of four previous series are compared with that of the



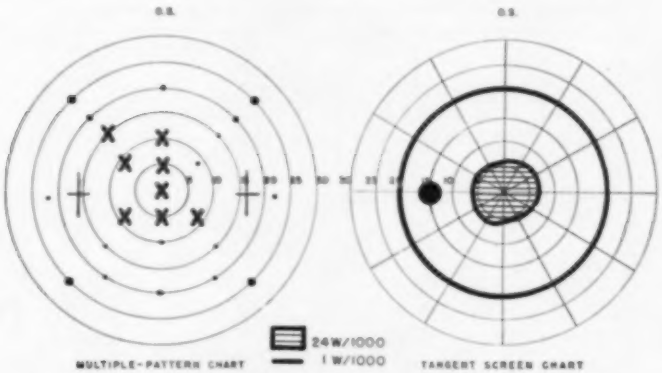


Fig. 4. (Top). Case No. 5, retinal hemorrhages, old traumatic.
Fig. 5. (Bottom). Case No. 7, disciform degeneration of the macula.

present author. The present study yielded a referral rate of 3.1% and an over-referral rate of 15.8% of these. The over-referral rate is compared with that of the above mentioned authors and a rather wide range is found.

Sample Multiple-Pattern charts and tangent screen charts for five cases are included to demonstrate typical results of the test.

A need for further evaluation of the screener's under-referral rate is pointed out.

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TRANSACTIONS OF THE AMERICAN ACADEMY OF OPTOMETRY

A department devoted to announcements, reports, appointments, organization data, news, professional problems and ideals, as these relate to the Academy.

ANNUAL MEETING, BRITISH CHAPTER

The annual meeting of the British Chapter, American Academy of Optometry, was held at the Raven Hotel, Shrewsbury, on April 19. The president, Clifford Hall, was in the chair, supported by vice-president Euin Steele and secretary Eric Bateman.

The secretary was able to report another year of excellent progress. New members, who had been admitted to the British Chapter during the past year, were welcomed. Progress had also been made in the research work sponsored by the British Chapter. In a further effort to encourage optical education it was decided to grant a scholarship to the value of twenty-five pounds to the London Course of Optometry.

Following the business meeting, a lecture-presentation by Mr. Norman Bier was open to members and friends.

Mr. Bier briefly described his theory and ideas of contact lens work and the remainder of the session was given to colored slides and a colored cinema film of his American visit. Also a recording was played of Mr. Bier being interviewed on a broadcast program by that well-known and controversial figure of American radio, John Wingate. John Wingate introduced Norman Bier as one of the world's great contact lens experts, and cross questioned him on the difference in British and American contact lens practice, and also asked several questions regarding conjunctivitis so that he could work in his cryptic crack of "Don't roll those bloodshot eyes at me." This recording was most interesting.

At the request of the president, a vote of thanks to Mr. Bier was proposed.

SYDNEY G. BURNLEY

THE RELATIONSHIP BETWEEN INTELLIGENCE AND THE REFRACTIVE STATE IN A SELECTED HIGH SCHOOL SAMPLE*

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Los Angeles, California
and
Monroe J. Hirsch‡
Ojai, California

INTRODUCTION

Historically, intelligence has been measured by pencil and paper tests. Most intelligence tests require a knowledge of symbols which, in large part, is derived from printed materials. Therefore, to acquire the information needed both to take the test and to perform well on it, one would have to make considerable use of his eyes. The role of vision in this respect has prompted many investigators to inquire if there is a relationship between vision and intelligence test scores, or between vision and intelligence.

Early studies sought to relate myopia to intelligence through the factor of occupation. It was believed that myopes engaged chiefly in occupations involving near visual tasks, and that these occupations were precisely those requiring the most intelligence for their performance.[1, 2] The factor of economic status was also introduced, since it was thought that the upper economic classes engaged chiefly in near work occupations, and that the lower income groups were largely confined to far point activities.[3] Thus, intelligence was related to the refractive state indirectly through the factors of type of work and socio-economic class.

Later investigators turned to a more direct investigation of the relationship between refractive error and intelligence. Pfingst, for example, cited a number of reports, each dealing with a case of feeble-mindedness associated with a considerable degree of hypermetropia.[4] An anatomical reason for this was put forth by Roberts, who reported that sex-linked microphthalmos and intelligence were associated, the failure of the neural tissue of brain and eye to develop indicating reduced intelligence and hypermetropia, respectively.[5]

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This anatomical argument was concurred in by Stocker, who observed in a group of 124 institutionalized children of subnormal intelligence significantly more hypermetropia than would be found in a comparable group of normal school children. According to Stocker, not only lowered intelligence, but reduction in the circumference of the skull indicated the under-development of the brain.[6] Kurz, upon examining 216 feeble-minded inmates from four to forty years of age in a Swiss institution, found more moderate and high degrees of hypermetropia among this group than would be present among normal persons of like ages. Like Stocker, Kurz believed this to be a demonstration of the relationship between under-development of the eye and a like condition of the brain.[7] Kirschen, studying the visual performance of mentally retarded children at the Modesto (California) State Hospital, found a considerably greater frequency of hypermetropia than in a comparable normal population.[8]

At the other extreme, Harman stated that high myopes are likely to be possessors of greater than average intelligence; yet paradoxically he feared that too intensive use of the myope's "delicate" eyes in close work might result in school failure.[9] Von Moers-Messmer, reviewing the theories of the cause of myopia, concluded that myopia and high intelligence are associated.[10] Birnbaum believed that there is more myopia among intellectuals doing near work than among persons of the lower classes who do near work. He also expressed the opinion that myopia is nature's ocular adaptation to the demands of civilization, and that the law of the survival of the fittest may have helped eliminate myopes from "uncultured" (i.e., preliterate) societies.[11] Clark, though subscribing to the near work theory concerning the cause of myopia, objected to the idea that myopia is nature's answer to civilization's demands on the eye,[12] an objection fully shared by Hirsch, who finds no evidence to sustain this belief.[13]

The problem of intelligence as it pertains to the eye was handled quite differently by Blanchard. Concerning this problem in elementary schools, she comments that a child who is classed as mentally retarded may simply be experiencing difficulty in reading. Persistence of such a difficulty may ultimately lead to school failure, as well as to personality and behavior problems.[14] Excluding the factor of astigmatism, one would expect the myope to experience little difficulty in reading, since his far point is likely to be close to the reading distance. On the other hand, close work exacerbates the hypermetrope's problem of accommodation, especially if accompanied by a high ACA ratio. Logically, then, we might infer from Blanchard's observations that it would most likely

be the hypermetropes who would appear to be mentally retarded.

This inference tends to be confirmed by the work of Schwartz, who found that the poor readers were primarily the hypermetropes. The reason for this, he states, is that the excess accommodation involved often results in the child's losing his place on the page, especially in the short period of time during which the eye shifts from the end of one line to the beginning of the next. While this is being done, the ciliary muscle relaxes, and, as the reading continues, the effort to make the relaxed muscle again contract becomes increasingly arduous. Of 1,100 poor readers analyzed by Schwartz, 58 per cent were anastigmatic hypermetropes, whereas only 3½ per cent were anastigmatic myopes.[15]

Another investigation of schooling and vision was undertaken by Heinonen, who found the usual increase in the frequency of myopia in the higher grades. Although he believed close work to be a factor, Heinonen thought that the chief reason for the relationship was the fact that myopes are the more intelligent part of the population, and it is the more intelligent persons who are most likely to embrace formal education.[1]

Goodsell determined the refractive error of 134 students in Los Angeles by retinoscopy, and also tested for visual acuity and muscle function.[16] She then clasified the "ocular conditon" as I, II, or III, I representing the best, and III the poorest, condition. To the same group Goodsell administered the Terman Group Test of Mental Ability, Form A, and, from the result, classified IQ in three categories, class I representing an IQ of 105 or over, class III as IQ of 89 or lower, and class II the IQ scores between these limits.

Upon comparing the number of students who fell within each class for both refractive error and intelligence, she found more students ranked higher on the IQ categories than on the eyesight classification. From this, it was concluded that high intelligence and mental ability are not dependent upon perfect eyesight. Logically, this would appear to require that a relationship between intelligence and refractive state had been determined *a priori*, since otherwise a comparison between the two classifications would be difficult to evaluate. Such a demonstration was not attempted. Goodsell's data also seemed to suggest that eyesight improves as successively higher grades in school are examined, a finding which is not encountered in most studies of this nature.

Perhaps the most satisfactory investigation so far made is the one undertaken by Hirsch.[13] Hirsch's findings are based upon a careful retinoscopic examination of 554 elementary and secondary school students between the ages of six and seventeen in Ohio. The data were

then correlated with the IQ scores derived from the Stanford-Binet test (administered chiefly to the younger pupils) and from the California Test of Mental Maturity. The correlation coefficient was —0.19, with a probability of less than 0.001. Although this was statistically significant, the predictive value of this magnitude of the correlation coefficient was found to be negligible. That is, although the myopes tended to have higher IQ scores, and hypermetropes lower scores, one could not confidently predict that a student with a given amount of myopia or hypermetropia would have a given intelligence quotient, nor the reverse.

Hirsch concluded that the association between moderate refractive errors and moderate intelligence was slight, since only six per cent of the variance in intelligence test performance was associated with variance in the refractive state of the eye for those subjects between 14 and 17 years of age. Furthermore, it was pointed out that, inasmuch as association does not reveal causation, it is not possible to determine whether intelligence determines the refractive state or the reverse. In fact, the results may merely indicate that children with certain refractive states are better equipped visually to take group intelligence tests than other children.

In the comprehensive Pullman (Washington) study conducted by Young, the relationship between the measured static refraction and intelligence (as determined by the Stanford-Binet test) was investigated. For the seven occupational groups used by Young, the IQ-refractive error correlation coefficients fell within the range of —0.22 to +0.16. Since none of these coefficients differed significantly from a zero correlation coefficient, Young concluded that there is no relationship between the IQ and the refractive error.[17]

A sociological examination of the general relationship between physical traits and mental and social development has led Hankins to declare that there is no physical trait which appears to have a significant correlation with mental age, and he regards physical and mental development as being almost entirely distinct.[18]

RESULTS AND CONCLUSIONS

The sample whose responses constitute the basis for the data here reported has been elsewhere described, together with the methods by which the refractive state was determined.[19] The age range of the sample was from 13.5 to 17.9 years. With fewer than half a dozen exceptions, the 414 students comprising the sample had taken the California Test of Mental Maturity (CTMM), which examines both verbal and non-verbal factors in intelligence. The resulting score is therefore a composite of two scores—one termed a language IQ and the other a non-

language IQ. The latter includes a mathematical perception of objects, in that these represent geometric forms. Hence the CTMM tests the three types of abilities found in most general tests of intelligence: verbal, numerical, and spatial.[20]

The results of these tests, which had been administered and scored by presumably competent school personnel, were made available to the authors by the high school. The test scores ranged from 63 to 146. The Pearsonian (product-moment) correlation coefficient was utilized to correlate these IQ scores with the refractive state for the entire sample. The correlation coefficient, r_s was —0.082, with a probability greater than 0.10. Therefore, although the trend found by Hirsch is duplicated here—namely, for the myopes to be the more measurably intelligent—the observed relationship is not significant. The results obtained could be due to chance since, if the true r were zero, an observed r could differ by the amount found in this investigation over 10 times in 100 samplings. Furthermore, the obtained r is much too low to be of any predictive value.* It may, therefore, be concluded that the relationship betwen refractive state and intelligence is a negligible one, and neither factor can be utilized as a cause to "explain" the other.

The literature suggests that a correlation may be found between refraction and intelligence where a visual problem exists, but this may very well be a correlation between the refractive state and the IQ test score, rather than the underlying ability which the intelligence test purports to measure. It appears that those who experience reading difficulties may do poorly on intelligence tests. To the extent that the reading disability is visually grounded, the refractive error may be indirectly associated with the IQ test performance. Physiologically, it seems that visual discomfort is much more likely to be encountered by the hypermetropic, rather than the myopic child, and it might therefore be inferred that the former will avoid reading and consequently be handicapped on intelligence tests. However, in such a test as the CTMM, both language and non-language items are employed. Assuming the visual connection with reading problems, and assuming the influence of the latter on language item scores, it is not so apparent why this effect should extend to the non-language items, which were designed specifically to overcome this influence.

Actually, although tests of intelligence undeniably involve visual abilities, it should be recognized that intelligence itself, which may be

*It was found unnecessary to partial out age, since neither the IQ-refractive state correlation nor the age-refractive state correlation was significant. Therefore, even if the age factor had been partialled out, a significant correlation between intelligence test score and refractive error could not have been obtained.

broadly defined as the ability to apprehend and solve problems,[20] is considerably conditioned by one's social interaction and group experiences. Except for obviously extreme visual impairment, one's functioning in society is ordinarily not determined by his visual performance, and, from a sociological point of view, there is little reason to expect a high correlation between the refractive state and intelligence. The quantitative studies of this relationship seem to support this conclusion.

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PRESENT STATUS OF CONTACT LENS PRACTICE*

The present status of contact lens fitting is interesting and also controversial and subject to many personal opinions. In some respects the present is not markedly different from the past as the variations are only in degree. Contact lenses are being used for the same reasons: the same problems exist with variations: plus the same attitudes and unfortunately in some quarters the same commercialisms.

In 1942, Obrig wrote, "Contact lenses have been used to correct errors of refraction: as a protective device for the eyes against undesireable fluids, gases or solids: as a valuable aid in the treatment of several pathological eye conditions: as a valuable aid to vision where the wearing of spectacles is impossible or impractical: as a vocational aid to vision, and as the only refractive device which will give useful

*Read before the Spring Educational Forum of the Ohio State Optometric Association and the School of Optometry, The Ohio State University, Columbus, Ohio, May 18, 1958.

vision in certain abnormal eye conditions." Everything he said then is true today in contact lens practice. However, there is one idea that may be added, "The substitution of contact lenses for spectacles in an increasing number of cases." We might also add, but not so definitely, the possibility of some myopia control and their use in the treatment of squint and amblyopia.

Someone, in illustrating his belief in the optometric future of contact lenses in private practice, has said, "Twenty-five per cent of the traffic and 50 per cent of the income will be the result of contact lens service in an optometric office."

It is no longer necessary to go through the general trial and error procedures, or the taking of impressions, to obtain satisfactory results. Our newer graduates have never had the experience of taking impressions to get fitting results. Nor, do they have the selling job that we experienced a few years back. Not long ago it was difficult to convince the patient needing contact lenses that these were the answer to their problem. The opposition was not just on the part of the patient. There was also the problem of overcoming the ignorance and prejudice of the patient's relatives and friends. Today, patients are apt to ask for contact lenses and even go elsewhere when they are not available. Publicity dealing with contact lenses has been so widespread that it has created a desire to wear them on the part of many patients.

During the period after 1940 courses in contact lens fitting were given mainly to dispensing opticians with the result that the percentage of contact lenses prescribed but not worn, reached alarming proportions. At this time optometry had its opportunity to take over the field. The poor quality of work with the attendant bad publicity caused many dispensing opticians to drop the fitting of contact lenses. Some of them, looking to the future, opened their own contact lens laboratories and solicited laboratory work from the optometrist as well as the physician.

During this time a small number of optometrists gave up general practice and devoted all of their time to contact lens fitting. Only a few of them were able to continue because of the reluctance optometrists had in referring patients to other optometrists. Many other practitioners, in addition, were perfectly willing to do a preliminary examination for a laboratory and collect a fee, knowing in most cases that the laboratory technicians would do the examination over again, as was frequently necessary.

Today, the situation is somewhat different due to the development of the various forms of corneal lenses. Some of the original laboratories are still in existence, supported mainly by men other than optometrists,

and many of those laboratories that dropped the work prior to 1950 are again in business. Today, with optometrists rapidly entering the field, the profession is attempting to regain lost ground by trying to interest all optometrists in doing this important work.

There are, in the writer's opinion, four factors present today that stand in the way of full professional approach and acceptance of contact lenses. These are, (1) the realization that contact lenses are a part of optometric service and not just a means of adding to income. (2) The insufficient training in contact lens clinical procedures given our undergraduate students in some of our schools. (3) The failure on the part of the optometrist to attend proper educational facilities for post-graduate training in clinical contact lens procedures, and (4) the necessity of State Optometric Associations insisting that members follow the same ethical practice concepts for contact lens fitting as they do for general optometric practice.

Let us review these points. First, the realization that contact lenses are a part of optometric service and not just a means of adding to income. To all of us concerned as we are with making a living, the temptation to argue the point frequently ends in one philosophy at professional meetings and another in actual practice. I do not believe that it is possible to maintain the professional approach, namely, the desire to give of your services, if the first consideration is "will it add to my income." Certainly we are free to estimate the value of our services, and we should not make this estimate too low, but in the final analysis our patients will determine the value of our services if we always prescribe only what is really best for them.

Next, the insufficient training in clinical contact lens procedures in some of our undergraduate professional courses, is a drawback. It is a fact today that at times instruction is given to those students who express a desire to specialize, and in other cases only the theory and demonstration seem to be the total extent of the course. Many optometrists who learn contact lens fitting through post-graduate courses and by practical experience know that when they finished their undergraduate training they were confident in all aspects of their general work and at a complete loss in the technique of contact lens fitting. The writer believes that all undergraduate students should be fully trained in contact lens fitting.

Then the failure on the part of some optometrists to attend proper educational facilities for post-graduate training in contact lens procedure is to be regretted. No one should discount the contributions made in this field by various manufacturers of contact lenses. Many of these

people are supreme in their work. Nevertheless, there is a wide variance between education which is coupled with selling a product and the recognized educational background of our full time faculty personnel. Both groups should be utilized in post-graduate training to the fullest extent.

And last, the necessity of having our State Optometric Associations require that members follow the same ethical concepts for contact lens fitting as they do for general practice, is a requirement. It is expected that the ethics of a profession are to be maintained not only by an individual in his office but must also be maintained throughout the entire program of referral of patients. Referral to individuals not eligible for membership in the association results in loss of prestige by the profession. Optometrists should consider that morally we are as responsible as is the individual in violation of ethics when we refer patients to the unethical non-member.

In spite of the problem, the situation from an overall standpoint is good. More and more optometrists are getting the training now needed, and are adding contact lens fitting to the services offered the public. In some instances ophthalmologists are beginning to realize that referral is a two-way street. And fortunately those optometrists now beginning the work are learning that there is no one pattern for fitting all patients. This is a realization that their education has just begun. The satisfaction received and the enthusiasm expressed has resulted in encouragement to others. The start that should have been made years ago is now evident. With improved service for patients this will result in much additional practice building. Certainly there are many patients that need contact lenses. Those who have realized this are not finding it difficult to maintain their proficiency in the art of fitting contact lenses.

As some are prone to think of contact lenses and their use in a narrow sense, I would like to repeat some of the unusual uses. First, in refractive conditions their use is frequently superior to spectacle lenses. This is particularly true in both monocular and binocular aphakic cases. The use of contact lenses in binocular aphakia has many advantages. There is the great reduction in the weight of the lenses, the greater field of view and practically no magnification disturbance in space perception. In monocular aphakia, binocular vision may be restored by reducing the disparity in the retinal image sizes, which is almost impossible with conventional spectacle lenses.

And, next, one should mention the kerataconus cases. The results obtained at times with contact lenses are almost unbelievable. Vision often increases from the spectacle correction of 20/400, to 20/30

and even 20/20 with contact lenses. Not only is it possible to increase the patient's vision in these cases, but many times if the lenses are fitted with a 2 mm. contact against the apex of the cone it seems to have a tendency to prevent the further progression of the cone.

Next in cases of irregular cornea these lenses have distinctive advantages. In an optical sense, the contact lens replaces the anterior surface of the cornea. The tear fluid filling in the irregularities underneath the contact lens again makes for visual acuity which in certain cases is impossible with spectacle lenses. The same is sometimes true with scarred corneas. Despite the presence of corneal opacities, remarkable improvement in visual acuity may be obtained with a regular or pinhole contact lens in many of these cases.

Some additional cosmetic uses of contact lenses should also be mentioned. They may be used to hide unsightly corneal scars or to cover a deformity. They may be used to reduce the pupil size and in cases of strabismus they have been fitted to restore the apparent parallelism of the visual axes when the deviating or squinting eye is blind. Further contact lenses are an invaluable means of corneal protection in such conditions as entropion with trichiasis and trachoma. In cases of albinism, aniridia and other abnormalities of the iris, contact lenses may be used to create a normal appearance and to restore visual functions.

As to the lenses now in use, it is evident that great improvements have been made. It would seem today that in many cases the lenses are better than the techniques of fitting. Many optometrists are prone to accept a new type lens as the final answer, forgetting that in spite of the obvious overall advantage of the micro lens that possibly for some patients a corneal or scleral lens might be more satisfactory. Mention might well be made of the suggested new bifocal contact lens proposed by Wesley. Surely this is an idea that warrants further investigation. It seems probable that the problems of fitting a suitable bifocal contact lens will be solved eventually.

In conclusion, optometrists should realize that no one lens or laboratory has all of the answers. As in your normal routine let the laboratories be a helpful adjunct to your office and not your office be an adjunct to the laboratories.

DAN G. HUMMEL, O.D.*

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CLEVELAND, OHIO

*Optometrist. Fellow, American Academy of Optometry. Diplomate, Contact Lens Section, American Academy of Optometry.

CORRESPONDENCE

A NOTE OF APPRECIATION ON THE SHEARD VOLUME FROM THE AUTHOR

This is the night of May Day and I am sitting in my library—thinking of the May Days of by-gone years when I was a boy and hung baskets on the doorknobs of the homes of the fair young girls or possibly chiefly to the (then) only girl: of my children and their pleasures on such occasions and, finally, of my grandchildren, of whom three are girls, now quite grown up and to whom I have sent our tokens of affection. The midnight hour approaches and I return to my surrounds to find a copy (presumably copy No. 1) of the *Sheard Volume—Selected Writings in Visual and Ophthalmic Optics*—now carrying many autographs of my friends and associates—lying at my right hand and, at my left hand, the manuscript of the book, galley and page proofs and so forth which have been kept for six months by the publishers and have just recently come into my possession to do with as seems best to me. In a way, then, this undertaking is now *fait accompli*, and I rejoice because of the splendid manner in which the volume has been made available to the patrons and sponsors of the Sheard Volume. Above all, I can only hope that the contents will serve to stimulate the thinking and improve the practices of men in optometry, ophthalmology and opticianry.

So, therefore, I am hanging a May Day basket, inscribed: "Many Thanks, Dear Friend," on the door of each and every one of you who made possible the publication of the Sheard Volume through your words of encouragement and expressions of pleasure that such a volume could be made available, and your willingness to become prepublication patrons and sponsors. And I am hanging a basket filled with additional kindly thought and words of appreciation to the members of the three committees and their chairmen and to the secretary of the American Academy of Optometry who acted as the catalyst, so to speak, between the author, the editors of the publishing company, the general committee and the publishers of the book.

I am pleased to say that all proceeds from the sale of the book are to go to the Sheard Foundation for Education and Research in Vision, Graduate School, The Ohio State University, Columbus, Ohio. An accounting is to be made each year by the publisher. The volume was published on October 1, 1957. As of January 1, 1958 (a period of three months), there was deposited in the Treasury of the State of

Ohio to the credit of the assets of this foundation nearly five hundred dollars. So we have another reason for saying "Many Thanks."

I have written quite a number of thank you notes and have had some personal visits with a number of the patrons and sponsors, but it is probable that I shall not be able to cover the whole list by personal correspondence. So I am taking this occasion to publicly express my appreciation of and gratitude for the many good things you have done for me over these many years.

CHARLES SHEARD, PH.D.

P.O. BOX 543
ROCHESTER, MINNESOTA

SPECIAL REPORT

CITATION OF J. H. PRINCE FOR THE B.O.A. RESEARCH MEDAL*

Glenn A. Fry

The ceremony about to be performed is most unusual. Periodically the British Optical Association awards a Research Medal. This year the B.O.A. has decided to award two medals, one to Mr. J. B. Davey and a second to Prof. J. H. Prince at The Ohio State University. Professor Prince spent last summer in Europe and so could not return to England to be presented with the medal at the Annual General Meeting as is usually the custom. Therefore, Mr. Giles, the B.O.A secretary whom many of you remember as the featured lecturer at one of our previous Spring Conferences, offered us the most unusual honor of including the presentation of the medal to Prof. Prince as a part of our program tonight. Because I have the distinction of being the only Honorary B.O.A. Fellow in this country, I have been selected to make the presentation.

The medal was established in 1952 and four of these medals have already been presented prior to this year: 1. Mr. F. A. Burnett Hodd for his work in retinoscopy; 2. Lord Charnwood for his work on binocular vision; 3. Mr. Edgar Fincham for his work on accommodation; 4. Mr. A. E. Turville for his work on the infinity balance test. Hence, I may say to you, Prof. Prince, that this medal is not only a

*Presentation of Research Medal of British Optical Association to Jack H. Prince, F.B.O.A. by Glenn A. Fry, Ph.D., at the Spring Educational Forum of the Ohio State Optometric Association and the School of Optometry, The Ohio State University, Columbus, Ohio, May 18, 1958.

token of the esteem of the members of our Association, but it carries with it the high distinction that you are being included in an array of talented and eminent men.

The award is made at the discretion of the B.O.A. Council for original research. The merit of the research is judged on the basis of (a) originality of conception, validity and ingenuity of experiment, and (b) the extent to which the research advances the science of ophthalmic optics or establishes knowledge by experimental testing of existing theories.

Jack Harvey Prince was born November 10, 1908, in London and received his early education in that city. His training in ophthalmic optics was obtained at the Northampton Polytechnic Institute. In 1926, he became a Fellow of the Spectacle Makers' Company and in 1929 a Fellow of the British Optical Association. Up until the war he practiced as an opthalmic optician. He also served as lecturer for the B.O.A. and the Institute of Ophthalmic Opticians. During the war he was employed in government research and in the same period was an Executive Council member of both the Joint Council of Qualified Opticians and the Association of Optical Practitioners. During this early period he published two books on ocular prosthesis: *Ocular Prosthesis* (1946), and *Recent Advances in Ocular Prosthesis* (1950). He became interested and active in the field of comparative anatomy of the eye and was elected a Fellow of the Royal Microscopical Society (1949) and a Fellow of the London Zoological Society (1949).

In 1946, he went to Australia because of the opportunity to study the unusual eyes of animals in that region. His studies in this field have culminated in the publication of two books: *Visual Development* (1949), and *Comparative Anatomy of the Eye* (1956). He is still registered as an optometrist in both Queensland and South Australia.

He came to The Ohio State University in 1952 where he became associated with Prof. Culler in the Department of Ophthalmology and where he is now an associate professor in that department.

Like Prof. Sheard he is an idealist and has worked toward harmonious relationships between optometry and ophthalmology. He has maintained active rapport with the School of Optometry and gives occasional lectures to our students. He and I have jointly conducted researches on visual acuity. He has been active in the affairs of the Institute for Research in Vision and is now its acting director.

Since being in this country he has become a Fellow of the American Academy of Optometry and a member of the following scientific societies: Society of Sigma Xi, Association of American Medical Col-

leges, American Association of University Professors, Association for Research in Ophthalmology, Ohio State Society of Clinical Research, and American Association for the Advancement of Science.

He is also a member of the Ohio State Committee of Medical Engineering. His recent research and published papers feature work on retinal and slit lamp photography, histology of the optic nerve and visual acuity.

I am pleased, therefore, to present to you on behalf of the B.O.A. the Research Medal for your past accomplishments and the prospect of greater things to come.

INSTRUMENT REVIEW

AO-SCHEPENS BINOCULAR INDIRECT OPHTHALMOSCOPE*

George P. Elmstrom†
El Segundo, California

Although the indirect ophthalmoscope was invented about the time that direct ophthalmoscope was, the indirect version never received much clinical interest. The interest directed toward the indirect type was primarily academic. The American Optical Company has developed a very real and substantial contribution to the eye professions with its new binocular indirect ophthalmoscope.

Unlike the old theoretical version, the AO-Schepens has a self-luminous source, 18 watts, operated from a transformer. The unit is stereoscopic permitting an observation of the fundus in such a way maximum clarity of minute details is possible. The interpupillary range is very wide, 58 to 76 mm. Three condensing lenses of ±20.00 D. small diameter, +20.00 D. large diameter, and +14.00 D. large diameter are supplied with the ophthalmoscope. The magnification of an emmetropic fundus is about 4½ X with the 14.00 D. lens. Figure 1.

The advantages of the indirect ophthalmoscope over the direct type are: stereopsis, strong illumination (but variable), low magnification with a wide field, rapid switch from one eye to the other, for comparisons, observation of extreme fundus periphery which is impossible with the direct version. The author has used the new AO-Schepens Indirect Binocular Ophthalmoscope with a number of patients

*Submitted on November 20, 1957, for publication in the June, 1958, issue of the AMERICAN JOURNAL OF OPTOMETRY AND ARCHIVES OF AMERICAN ACADEMY OF OPTOMETRY.

Fig. 1

with enthusiasm and a great deal of satisfaction. The instrument compliments, does not replace, the direct orthodox ophthalmoscope. One alteration would make the unit more practical for the practicing optometrist and that is changing the light source from transformer to a battery unit which would eliminate the cumbersome cord hanging down the back of the head of the examiner. (Cost $200.00)

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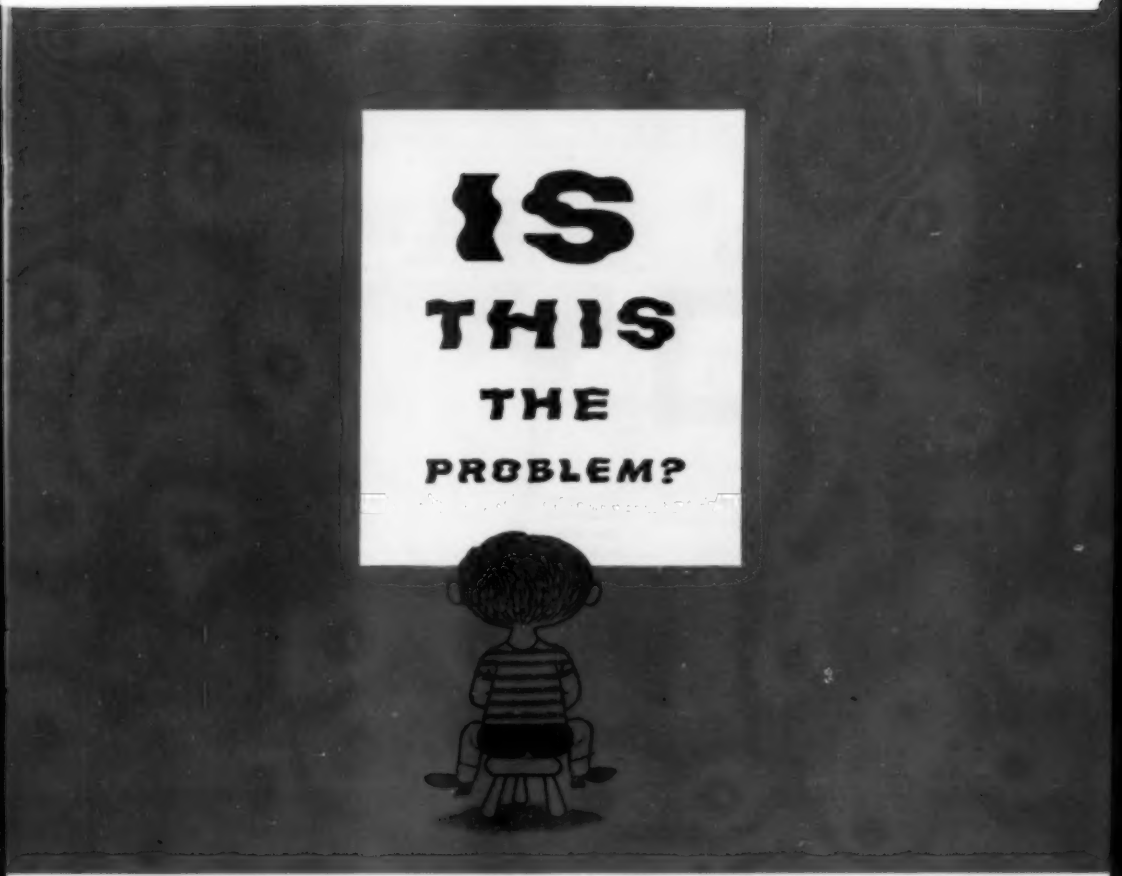
ANNOUNCEMENT

CONTACT LENS POST-GRADUATE COURSE AT PENN STATE

The Pennsylvania State College of Optometry announces a post-graduate course in the fitting of contact lenses by school faculty. The course will be of seven day duration, starting Sunday, July 13, and continuing through Saturday, July 19. The course will consist of 24 hours of clinical practice under the instruction of Dr. John C. Neill in the Contact Lens Clinic, and 18 hours of lecture work, by Drs. Neill, F. W. Sinn, O. G. Rybachok, and Harold Simmerman. All aspects of the prescribing and fitting of contact lenses will be covered. The class will be limited to 12 students. The fee for the course is $100 which is required in advance to reserve a place in the class. Information and application form may be obtained by writing the College, 6100 North 12th Street, Philadelphia.



Irregular astigmatism, keratoconus, or aberrations of the corneal surface are conditions which will not allow patients to see things as they really are. The variations in curvature of the front surface of the cornea will refract light to different distances and in different directions. The spectacle lens will do very little to correct the irregular refraction of light by the cornea. Something is necessary to regularize the curvatures of the cornea. Proper fitting of a contact lens will take care of these conditions which are otherwise uncorrectable by any other means.

Uncorrected, the anterior and posterior surfaces of the precorneal fluid will conform to the surface of the cornea and maintain the irregular curvatures. With application of a contact lens, the front surface of the precorneal fluid conforms to the regular surface of the contact lens, thereby creating a spherical eye out of an originally distorted curvature.

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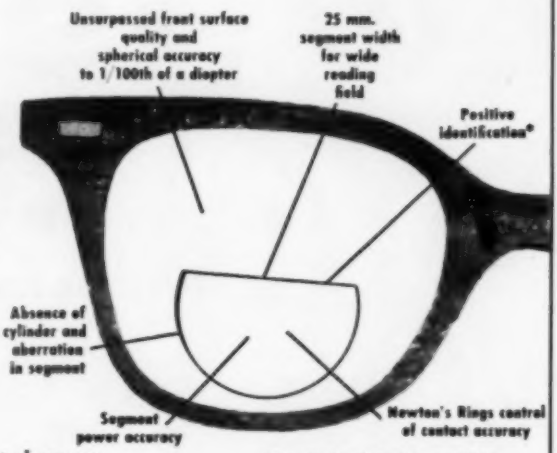
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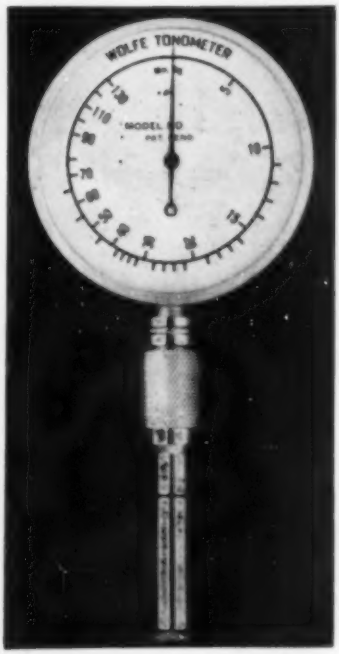

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